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DRAFT

BIOVENTING TEST WORK PLAN AND INTERIM RESULTS REPORT FOR FOUR BIOVENTING SITES HILL AIR FORCE BASE, UTAH

Prepared For

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

Ogden Air Logistics Center/EMR
Hill Air Force Base, Utah

ES ENGINEERING-SCIENCE

ES
Engineering-Science, Inc.
1700 BROADWAY, SUITE 900
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September 1992

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PART I
DRAFT TEST WORK PLAN
FOR FOUR BIOVENTING SITES
HILL AIR FORCE BASE, UTAH

Prepared for:

Air Force Center for Environmental Excellence
Brooks Air Force Base, Texas

and

Ogden Air Logistics Center/EMR
Hill Air Force Base, Utah

by

Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado

September 1992

A7-4-18

AQM01-01-0352

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PART I

TEST WORK PLAN

1.0 INTRODUCTION

This test work plan presents the scope of *in situ* bioventing pilot tests for treatment of fuel and solvent contaminated soils at four sites on Hill Air Force Base (AFB), Utah. The pilot tests have three primary objectives: 1) to assess the potential for supplying oxygen throughout the contaminated soil depth, 2) to determine the rate at which indigenous microorganisms will degrade fuel when stimulated by oxygen rich soil gas, and 3) to evaluate the potential for sustaining these rates of biodegration until fuel contamination is remediated below regulatory standards. If bioventing proves to be feasible at these sites, pilot test data can be used to design a full-scale remediation system and to estimate the time required for site cleanup.

Additional background information on the development and recent success of the bioventing technology is found in the referenced document entitled "Test Plan and Technical Protocol for a Field Treatability Test for Bioventing" (Hinchee et.al., January 1992). This protocol document will also serve as the primary reference for detailed procedures which will be used during the pilot test.

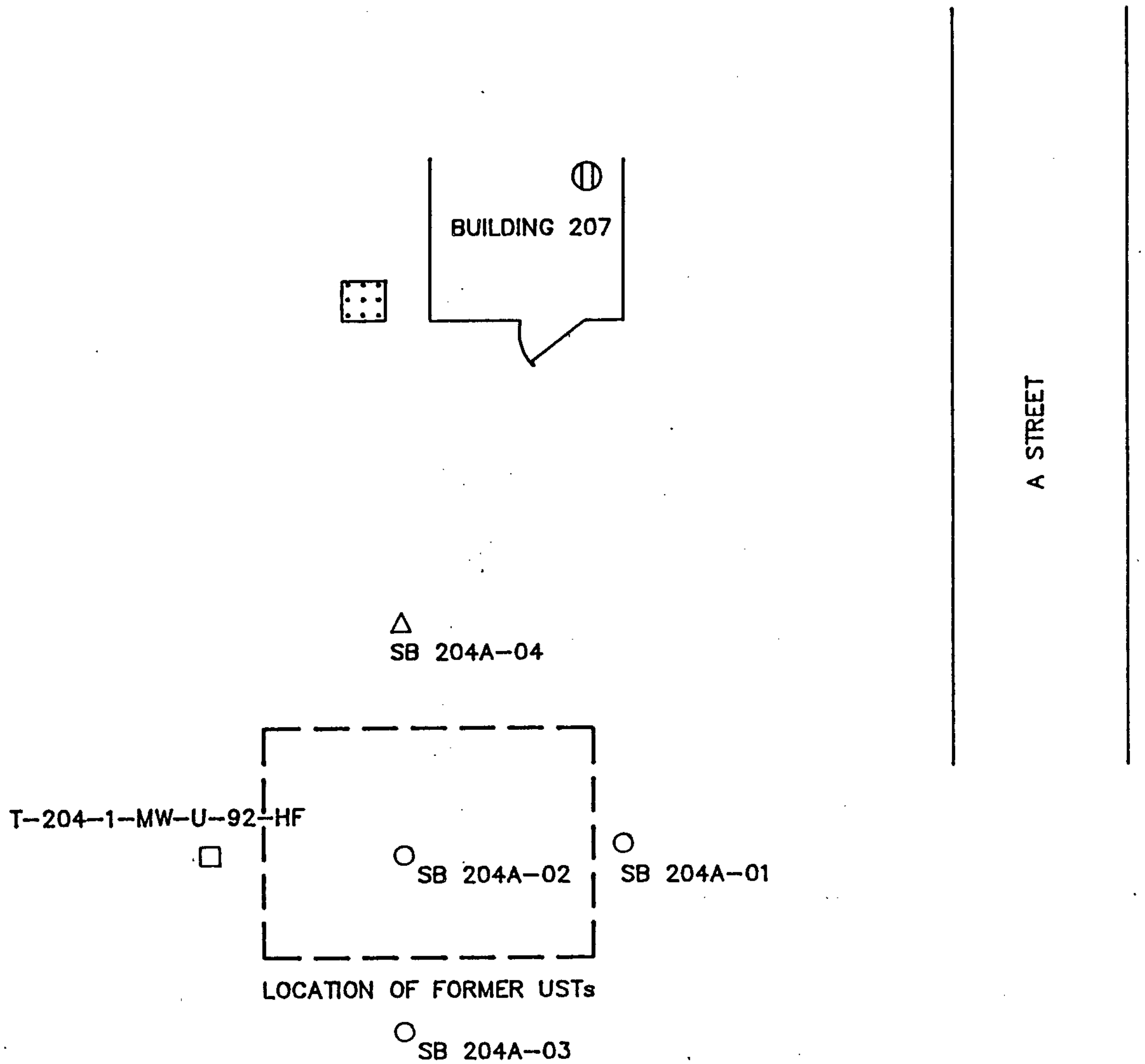
2.0 SITE DESCRIPTIONS

2.1 Site 204.1

2.1.1 Site Location and History

Site 204.1 is located approximately 50 feet southwest of A Street, which runs from northwest to southeast in the controlled area immediately west of the flight line. The site is located on flat land which is paved with concrete and asphalt. Figure 2.1 shows the location of Site 204.1 in relation to A Street and Building 207.

Two 12,000-gallon steel USTs, formerly containing diesel fuel, were removed from the site in October and November, 1987. In May, 1992, a subsurface investigation was conducted, which identified significant soil contamination. Groundwater monitor well T-204-1-MW-U-92-HF was installed, and four soil borings were drilled. A central vent well (SB204A-04) was constructed in one soil borehole, and vapor monitoring points were installed in three boreholes (Figure 2.1).



LEGEND

- △ CENTRAL VENT WELL (AIR INJECTION)
- ○ VAPOR MONITORING POINT
- □ GROUNDWATER MONITORING WELL
- ⏀ 110-VOLT RECEPTACLE POWER
- ⁞⁞ PROPOSED BLOWER LOCATION

INITIAL SOIL GAS CONCENTRATIONS

LOCATION	$\%O_2$	$\%CO_2$	HYDROCARBONS (ppm)
SB 204A-02	0.0	15.5	430
SB 204A-01 (8'-11')	9.8	7.9	100
SB 204A-01 (26'-29')	4.7	10.0	120
SB 204A-01 (33'-36')	5.5	9.5	120

SCALE: 1"=10'

FIGURE 2.1

SITE PLAN
SITE 204.1

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2.1.2 Site Geology and Extent of Contamination

Because the bioventing technology is applied to unsaturated soils, this section primarily addresses soils above the groundwater table. At Site 204.1, groundwater is encountered at a depth of approximately 150 feet and is not believed to be affected by contamination from the former USTs at the site.

Soils at Site 204.1 consist of alternating layers of sand, silty sand, and gravel. Bioventing is easily applied to these coarse-grained soils because there is more available pore space for soil gas flow. Engineering-Science has completed successful bioventing projects within similar soils, and we are confident that oxygen can be distributed in these soils. The soil vapor monitoring points will be used to examine the subsurface oxygen distribution pattern in the different soil depths and layers during the pilot test.

The primary contaminants on this site are diesel fuel residuals which have migrated to a depth of approximately 60 feet, and laterally to approximately 10 feet in all directions. Soil sampling yielded total petroleum hydrocarbon (TPH) concentrations ranging from non-detect (less than 5 mg/kg) to 1,500 mg/kg. Benzene, toluene, ethylbenzene, and xylenes (BTEX) and naphthalene were also detected at Site 204.1 (Montgomery, July 1992a).

2.1.3 Initial Soil Gas Characterization

On June 18, 1992, initial soil gas analyses were conducted at SB204A-01 and SB204A-02. Results are summarized on Figure 2.1. Carbon dioxide was present at elevated concentrations in all soil gas samples, and oxygen was at depleted levels, ranging from 0 to 9.8 percent, indicating the presence of biological activity in the soils and suggesting that bioventing may be a feasible technology for site remediation.

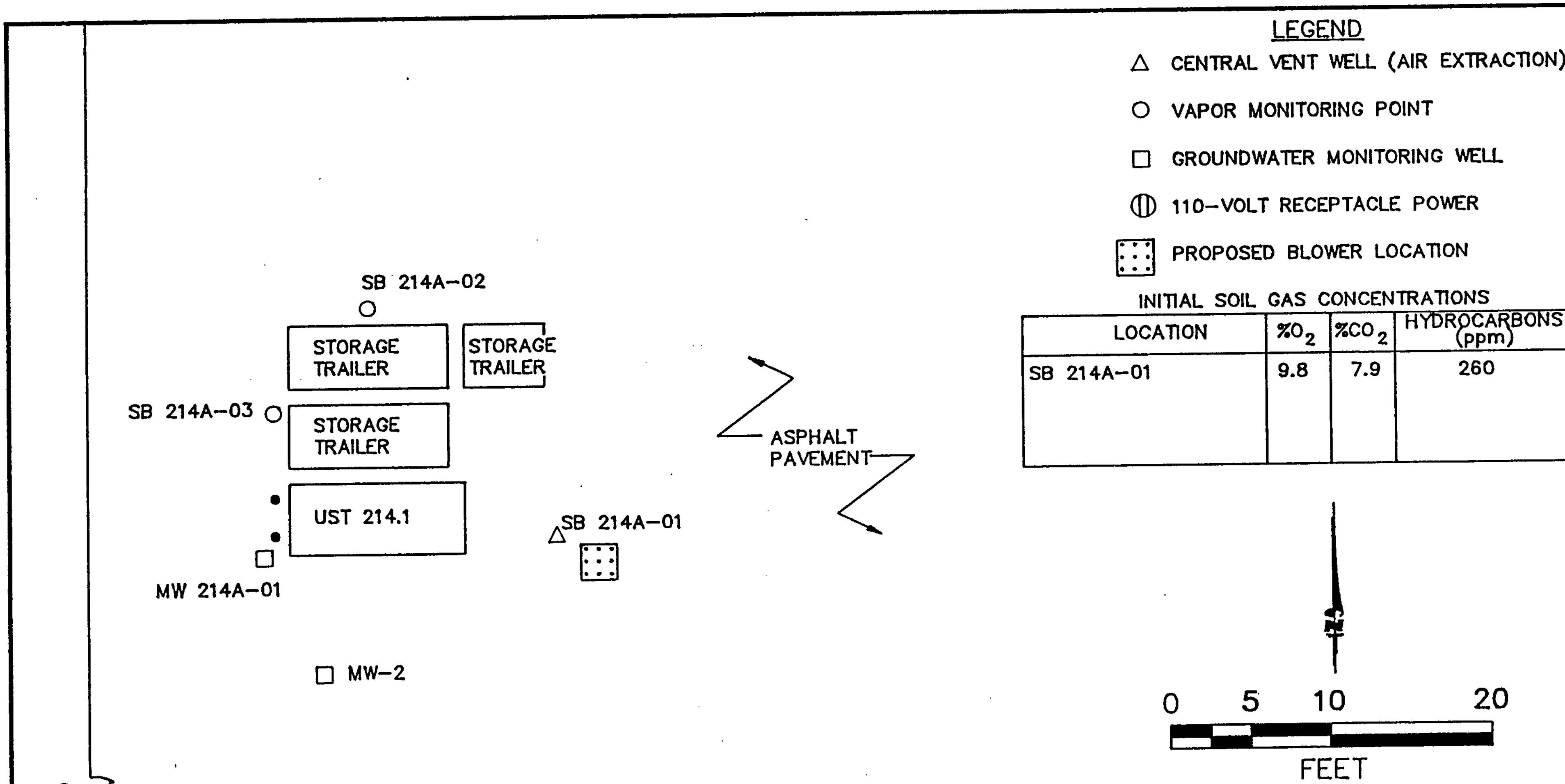
2.2 Site 214.1

2.2.1 Site Location and History

Site 214.1 is located approximately 50 feet north of Building 214 in the controlled area. The site is located on flat land which is paved with concrete and asphalt. Figure 2.2 shows the location of Site 214.1 relative to Building 214.

The UST adjacent to Building 214 (UST 214.1) was removed and replaced in December, 1989. UST 214.1 formerly contained stoddard solvent, which was used as a degreaser in Building 214. During the removal process, a hole and evidence of leakage were observed on UST 214.1. A new dual-chamber UST (214.2 and 214.3) was installed in the excavation left by UST 214.1. It currently stores new and used stoddard solvent (Montgomery, December 1991a).

A subsurface investigation starting in October 1991 identified soil contamination near the UST. Several soil borings were drilled, and a central vent well and two vapor monitoring points were constructed in three of the soil borings (Figure 2.2).



INITIAL SOIL GAS CONCENTRATIONS

LOCATION	$\%O_2$	$\%CO_2$	HYDROCARBONS (ppm)
SB 214A-01	9.8	7.9	260

FIGURE 2.2

SITE PLAN
SITE 214.1

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2.2.2 Site Geology and Extent of Contamination

The geology of Site 214.1 is similar to that of Site 204.1, and consists of the same coarse-grained alluvial deposits. The primary contaminant at Site 214.1 appears to be stoddard solvent which escaped from the former UST 214.1. Stoddard solvent consists of C_7 through C_{12} hydrocarbons, predominantly C_9 through C_{11}. Chemically, Stoddard solvent is a mixture of 30-50 percent straight and branched alkanes, 30-40 percent cycloalkanes, and 10-20 percent aromatics. All of the components of Stoddard solvent are considered to be biodegradable, given the proper environmental conditions. Soil samples collected from native soils beneath the former UST, at the time of its removal, contained 22,500 and 36,000 mg/kg of TPH as stoddard solvent. Contaminated soils were not removed. At SB214A-01, TPH was detected at a concentration of 36,200 mg/kg in a sample collected from 11 to 12 feet below ground surface. Toluene, ethylbenzene, and total xylenes were also detected in this sample at respective concentrations of 1,150 micrograms per kilogram (μg/kg), 5,840 μg/kg, and 65,800 μg/kg, respectively. No TPH or BTEX contamination was detected above action levels in any other samples collected from the site. Thus, contamination appears to be limited to an area within approximately 15 feet of the UST (Montgomery, December 1991a).

2.2.3 Initial Soil Gas Characterization

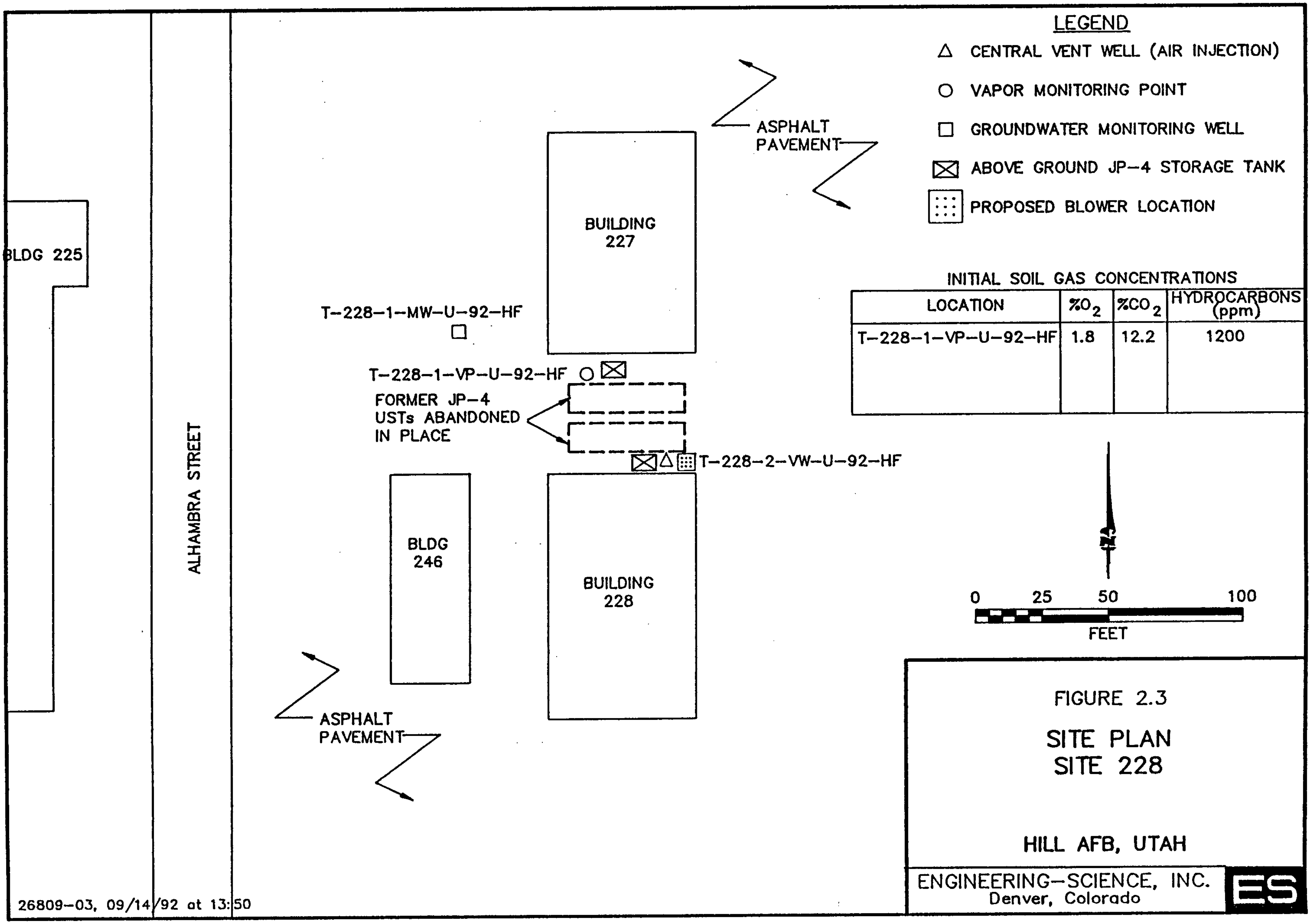
On June 18, 1992, initial soil gas analyses were conducted at Site 214.1. Soil gas could not be extracted from SB214A-02 or SB214A-03 due to subsurface blockage, possibly because the vapor probe tubing had been squeezed shut by the weight of the sand pack. Results from SB214A-01 are summarized on Figure 2.2. Oxygen was present at 9.8 percent in the sample collected from SB214A-01, which seems to indicate that oxygen is already available in site soils at levels sufficient to support aerobic biodegradation of fuel residuals. However, the vent well is screened to a depth of approximately 60 feet and contamination appears to be limited to the upper 43 feet of the soil column based upon field headspace results. The oxygen in the sample extracted from SB214A-01 is suspected to come from deeper non-contaminated soils, and the upper 15 feet of highly contaminated soil could be under anaerobic conditions. Thus, bioventing may be required to remediate soil at Site 214.1.

2.3 Site 228

2.3.1 Site Location and History

Site 228 is located approximately 150 feet east of Alhambra Street, between Buildings 227 and 228 in the controlled area. The site is located on flat land, entirely paved with asphalt. Figure 2.3 shows the location of the site in relation to Alhambra Street, Building 227, and Building 228.

The primary contaminant at Site 228 is JP-4 jet fuel. The source of contamination, two 25,000-gallon steel USTs between Buildings 227 and 228, were abandoned in place on October 22, 1991 by draining them and filling them with sand. The majority of the soil contamination on the site is thought to be the result of spills and leaks associated with these USTs.



INITIAL SOIL GAS CONCENTRATIONS

LOCATION	$\%O_2$	$\%CO_2$	HYDROCARBONS (ppm)
T–228–1–VP–U–92–HF	1.8	12.2	1200

FIGURE 2.3

SITE PLAN
SITE 228

HILL AFB, UTAH

2.3.2 Site Geology and Extent of Contamination

The geology of Site 228 is similar to that of Sites 204 and 214.1, and consists of coarse-grained alluvial deposits. The response of site soils to bioventing is expected to be similar to that of Sites 204 and 214.1.

The primary contaminant at Site 228 is JP-4 jet fuel, which either escaped from the two abandoned USTs or was spilled during filling activities. TPH was detected in the vapor probe borehole at 6,500 mg/kg, between 28 and 28.5 feet below the ground surface. In the vent well borehole, TPH was detected at a concentration of 5,000 mg/kg at 27.5 to 28 feet below ground surface. Naphthalene was detected in these samples at concentrations ranging from 0.31 to 3.3 mg/kg, and BTEX constituent were also detected at concentrations ranging from 0.007 to 260 mg/kg. No petroleum contamination was detected at depths over 30 feet below the ground surface. The lateral extent of contamination is approximately 10 feet from the USTs, except in the northeast corner where it appears to extend only 5 feet away from the USTs (Montgomery, July 1992c).

2.3.3 Initial Soil Gas Characterization

An initial soil gas sample was collected from vapor probe T-228-1-MW-U-92-HF on June 18, 1992. Results are tabulated on Figure 2.3. Oxygen was present at only 1.8 percent in the sample, indicating the presence of biological activity in the soil and suggesting that bioventing may be a feasible technology for site remediation.

2.4 Site 924

2.4.1 Site Location and History

Site 924 is located approximately 100 feet north of Second Street and directly west of Building 924, the base service station. The site is located on flat land, which is not currently paved because of earth working activity. The site will be covered with asphalt pavement at a later date. Figure 2.4 shows the location of Site 924 in relation to Building 924 and Second Street.

Four 12,000-gallon steel USTs were recently removed from Site 924. Two tanks stored unleaded gasoline, and two tanks stored diesel fuel. The tanks had been installed in 1969. At the time of tank removal, signs of contamination were observed. The extent of contamination is not yet fully defined. The UST excavation was backfilled with soil that had originated in the excavation, plus some clean fill material. During backfilling activities, a bioventing system was installed in the floor of the excavation. A section of 4-inch diameter, perforated pipe was installed running east-west across the floor of the excavation, and four soil gas probes were installed at each corner of the excavation floor at a depth of 12 feet below ground surface (Figure 2.4). Two other soil gas probes were installed at a depth of five feet.

2.4.2 Site Geology and Extent of Contamination

Soils at this site consist of clean sands and silty sands. Groundwater is encountered at a depth of approximately 150 feet.

Although the extent and concentration of contamination has not been fully defined, the site is thought to be contaminated with diesel fuel and unleaded

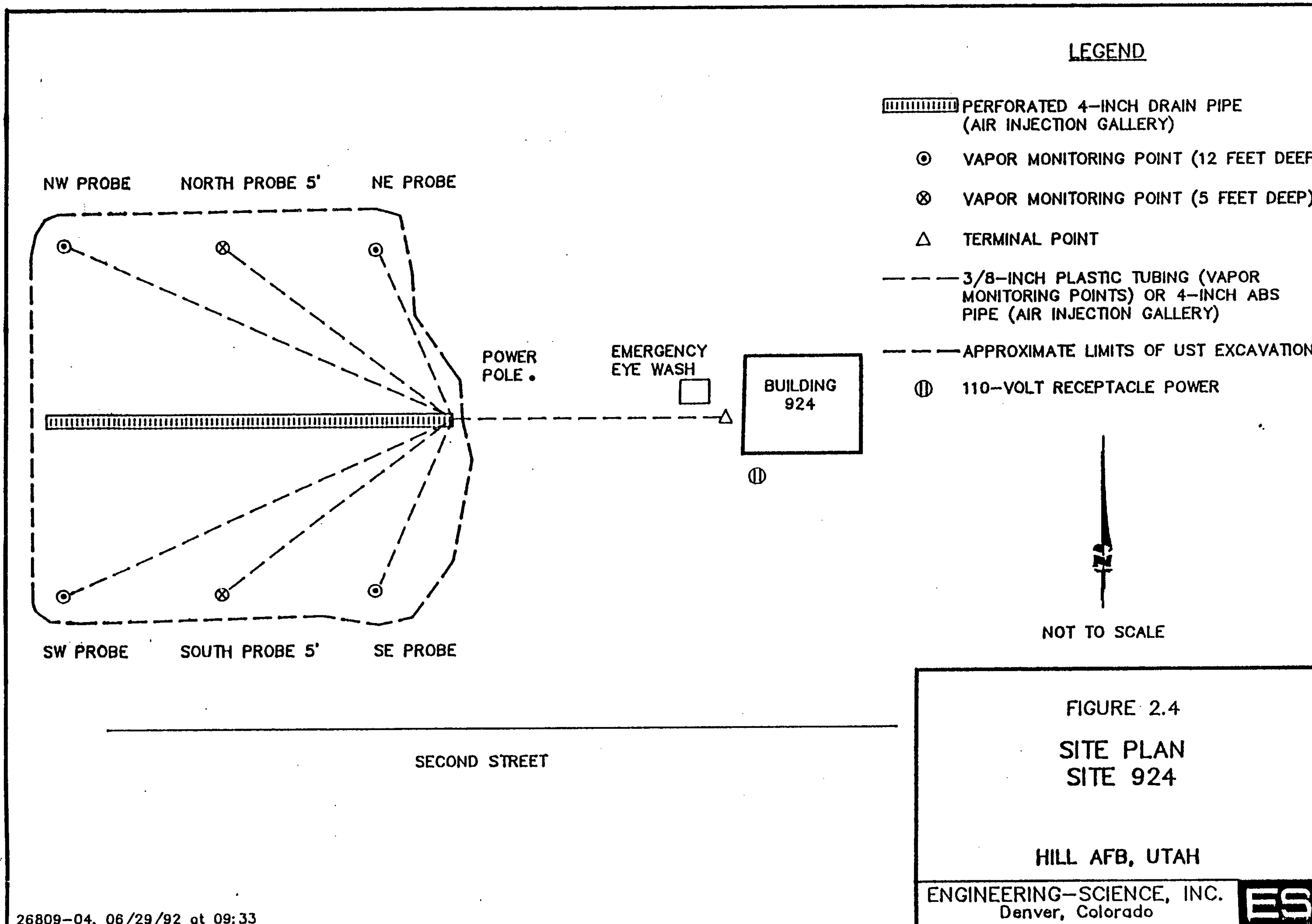


FIGURE 2.4

SITE PLAN
SITE 924

HILL AFB, UTAH

ENGINEERING-SCIENCE, INC.
Denver, Colorado

gasoline from the four former USTs on the site. Thus, potential contaminants include BTEX constituents present in gasoline and diesel fuel and PAHs that are found in diesel fuel.

2.4.3 Initial Soil Gas Characterization

Initial soil gas samples from Site 924 were collected and analyzed on June 18, 1992. Results are summarized in Table 2.1. Oxygen was not present in either the SE Probe or the South Probe, and oxygen was present at concentrations below 5 percent in the SW probe and the vent pipe. Carbon dioxide was present at concentrations over 10 percent in these four samples, and hydrocarbons were present in elevated concentrations at the SE probe and the South Probe. These results suggest that there is biological degradation of fuel in soils on the south side of the former UST excavation, and that bioventing may be a feasible technology for site remediation.

Soils on the north side of the former UST excavation appeared to contain much less fuel contamination. Oxygen in soil gas samples from the north side of the excavation contained oxygen at concentrations ranging from 9.5 to 14.2 percent.

3.0 SITE SPECIFIC ACTIVITIES

The purpose of this section is to describe the work that will be performed by ES at each of the four bioventing sites at Hill AFB. Vent wells and vapor probes have already been installed on the sites by other Air Force subcontractors. Therefore, no drilling will be performed. Existing groundwater monitoring wells will not be used during these pilot tests. The screened intervals of these monitoring wells occur well below 100 feet below the ground surface, and contamination at these sites is generally limited to the upper 30 feet of the unsaturated zone.

Activities that will be performed at each site include *in situ* respiration tests, an air permeability test, and the installation of a long-term bioventing system at each site. The objective of the *in situ* respiration test is to determine the rate at which soil bacteria degrade petroleum hydrocarbons. Respiration tests will be performed at every vapor probe and vent well where bacterial degradation of hydrocarbons is noted. These points are characterized by low oxygen levels and elevated carbon dioxide concentrations in the soil gas. Air will be injected at each point containing low levels of oxygen (below 5%, approximately) for a 12-hour period to oxygenate local contaminated soils. At the end of the 12-hour air injection period, the air supply will be cut off and oxygen and carbon dioxide levels will be monitored for the following 48 hours. The decline in oxygen and increase in carbon dioxide concentrations over time will be used to estimate rates of bacterial degradation of fuel residuals. Helium will also be injected at one point on each bioventing site to estimated oxygen diffusion rates in site soils.

The objective of the air permeability test is to determine the extent of the subsurface that can be oxygenated using one air injection or extraction unit. At each site, air will either be injected or extracted from the existing 4-inch diameter vent well using a blower unit, and pressure (during injection) or vacuum (during

TABLE 2.1

INITIAL SOIL GAS CONCENTRATIONS AT SITE 924

Location	Hydrocarbon Concentration ppmv	Oxygen Concentration % O2	Carbon Dioxide Concentration % CO2
4-inch Venting Pipe	88	1.6	13.8
SE Probe	>10,000	0.0	19.5
South Probe 5'	>10,000	0.0	20.0
SW Probe	110	4.0	10.6
NE Probe	190	14.2	5.4
North Probe 5'	205	12.5	7.3
NW Probe	90	9.5	6.8

extraction) response will be measured at existing vapor probes with differential pressure gauges to determine the region influenced by the unit. Oxygen will also be monitored in the vapor probes to ascertain that oxygen levels in the soil increase as the result of air injection/extraction. One air permeability test will be performed at each site. Each test will last for 4 to 8 hours.

A long-term bioventing system will also be installed at each of the four bioventing sites. An electrician subcontracted to ES will be brought on base to hook into existing power and assist in wiring the blowers to line power. Each blower will be housed in a small, prefabricated shed to provide protection from the weather. Each system will be in operation for one full year, and ES personnel will be onsite in November 1992 and July 1993 to conduct *in situ* respiration tests to monitor the long-term performance of these bioventing systems. Weekly system checks will be performed by Hill AFB personnel. If needed, major maintenance of the blower units will be performed by ES-Salt Lake City personnel. More detailed information regarding the test procedures can be found in the "Test Plan and Technical Protocol for a Field Treatability Test for Bioventing" (Hinchee et.al., January 1992).

3.1 Site 204.1

At Site 204.1, respiration tests will be performed at SB 204A-02 and SB 204A-01 (27 to 28 feet bgs), based upon initial soil gas sampling. During the initial site visit on June 17-18, 1992, soil gas from the vent well, SB 204A-04, was not sampled due to the unavailability of 110-volt power to operate the purge pump. If initial oxygen levels at SB 204A-04 are low (below approximately 5%), an *in situ* respiration test will also be performed at this point.

The air permeability test at Site 204.1 will involve air injection. There are no buildings in the immediate vicinity of the site other than Building 207, and the contaminant at the site is diesel fuel. Therefore, the potential for driving fuel vapors into basements and other confined spaces is minimal. Because 110-volt receptacle power will be available at the site, the air permeability test may be performed either before or after the installation of the long-term bioventing system.

The configuration of the proposed long-term blower system for Site 204.1 is illustrated in Figure 3.1. A weather proof disconnect switch and starter will be mounted on the southwest wall of Building 207, and the blower will be placed on the south corner of the building, as depicted in Figure 2.1. The subcontracted electrician will assemble the electrical system and connect it to existing line power. A 1.5-inch manifold will run from the blower outlet port to SB 204A-04. The manifold will be anchored to prevent the well casing from being broken. A 1-horsepower blower, powered by 110-volt electricity, is expected to be sufficient to enhance oxygen levels in the entire contaminated zone.

3.2 Site 214.1

Site 214.1 is illustrated in Figure 2.2 along with initial soil gas measurements that were made on June 18, 1992 at the vent well. Soil gas could not be extracted from either vapor probe during the initial site visit due to subsurface blockage. Although further attempts to extract soil gas will be made, ES does not anticipate that these

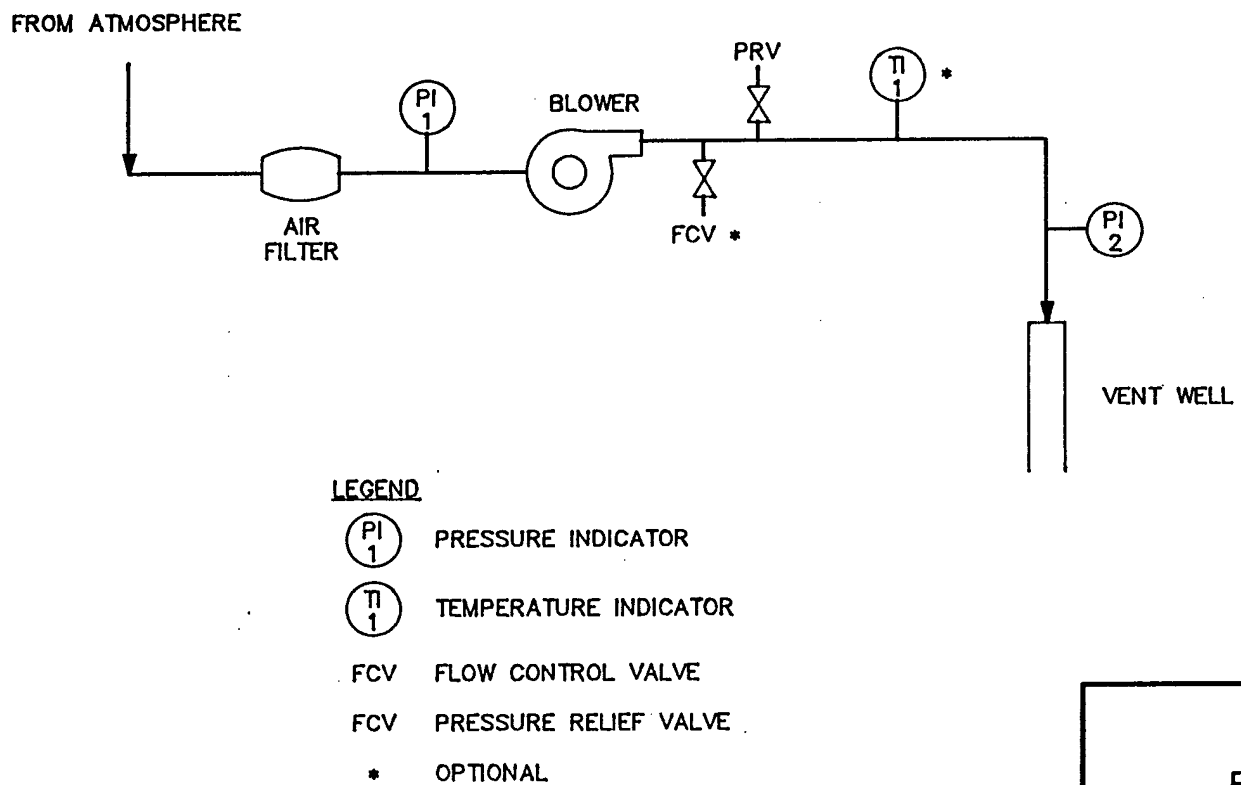


FIGURE 3.1

BLOWER SYSTEM INSTRUMENTATION DIAGRAM FOR AIR INJECTION

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points can be utilized for the pilot test. 110-volt receptacle power is available in Building 214.

A respiration test will be performed at SB 214A-01 using compressed air/helium. If soil gas can be extracted from SB 214A-02 or SB 214A-03, respiration tests will be conducted at these locations, provided that initial oxygen levels are low (below approximately 5 percent).

The air permeability test at Site 214.1 will involve air extraction due to the close proximity of Building 214. The air permeability test will only be performed if the existing vapor probes are functional, since the vapor probes will be required to monitor vacuum and oxygen response.

The configuration of the proposed long-term blower system for Site 214.1 is illustrated in Figure 3.2. A weatherproof disconnect switch and starter will be mounted on an existing instrument panel just north of the UST, and the blower will be placed at the southeast corner of the UST near SB214A-01. The electrician will assist in assembling the electrical system and connecting it to existing line power.

3.3 Site 228

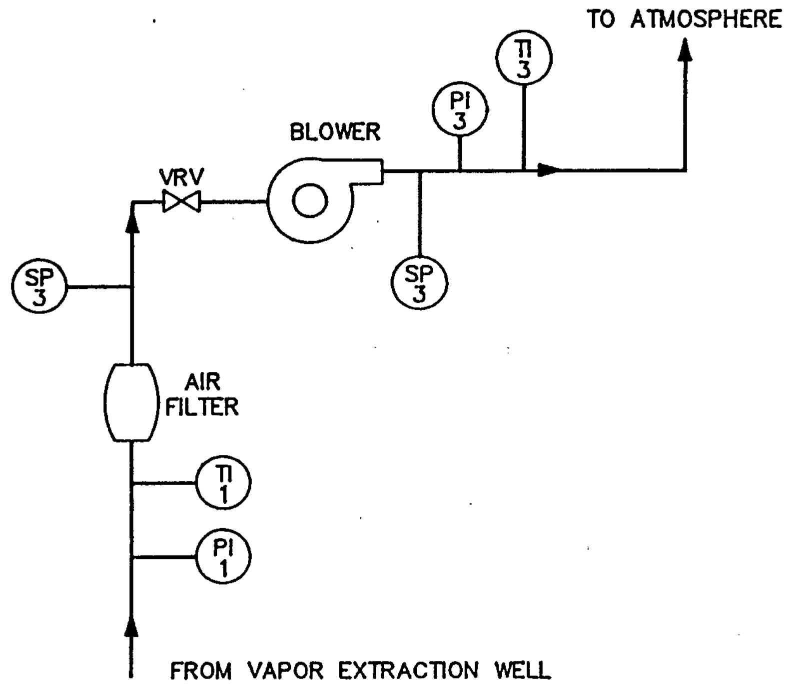
At Site 228, a respiration test will be performed at monitoring point T-228-1-VP-U-92-HF based upon low oxygen levels discovered during initial soil gas sampling. During the initial site visit on June 17-18, 1992, soil gas from the vent well, T-228-1-VW-U-92-HF, was not sampled due to the unavailability of an explosion proof 110-volt power circuit to operate the purge pump. A respiration test may also be conducted at the vent well if permission is given to temporarily operate standard 110-volt power in this area, which requires explosion-proof power for permanent electrical fixtures.

The air permeability test at Site 228 will involve air injection. Buildings 227 and 228, adjacent to the site, have no basements. Therefore, the potential for driving fuel vapors into basements and other confined spaces is minimal. Also, buildings 227 and 228 are equipped with explosion-proof power supplies. Because the use of standard 110-volt electrical power may not be allowed, the air permeability test may have to be performed after the installation of the long-term bioventing system.

The configuration of the proposed long-term blower system for Site 228 is illustrated in Figure 3.1. An explosion proof disconnect switch and starter will be mounted on the north wall of Building 227, and the blower will be placed next to the vent well as depicted in Figure 2.3. The subcontracted electrician will assemble the electrical system and connect it to existing line power. A 1.5-inch manifold will run from the blower outlet port to the vent well. A 1-horsepower blower, powered by 110-volt electricity, is expected to be sufficient to enhance oxygen levels in the entire contaminated zone.

3.4 Site 924

At Site 924, respiration tests will be performed at the vent pipe and all vapor probes on the south side of the excavation. Helium will be injected at one point to quantify diffusion rates.



LEGEND

SP 1	SAMPLE POINT
PI 1	PRESSURE INDICATOR
TI 1	TEMPERATURE INDICATOR
FCV	FLOW CONTROL VALVE
VRV	VACUUM RELIEF VALVE

FIGURE 3.2

BLOWER SYSTEM INSTRUMENTATION DIAGRAM FOR AIR EXTRACTION

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The air permeability test at Site 924 will involve air injection, since there are no buildings in the immediate vicinity of the former UST excavation. It is expected that a 2.5 horsepower blower powered by 220-volt electricity will be required to supply oxygen to the entire contaminated soil zone, since there appears to be a much larger volume of contaminated soil at Site 924 than the other three sites. The soil gas permeability test will be conducted using the long-term, 2.5 horsepower blower after it has been installed. However, the soil gas permeability test could also be conducted using a 1-horsepower blower operated by 110-volt receptacle power prior to the installation of the long-term system.

The configuration of the proposed long-term blower system for Site 924 is illustrated in Figure 3.1. A weatherproof disconnect switch and starter will be mounted on the west wall of Building 924, and the blower will be placed to the west of Building 924 as depicted in Figure 2.4. The subcontracted electrician will assemble the electrical system and connect it to existing line power. A 2.5 horsepower blower powered by 220-volt electricity will be used at Site 924, unless a 1 horsepower blower is found to be adequate.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The procedures that will be used to measure the air permeability of the soil and *in situ* respiration rates are described in Sections 4 and 5 of the protocol document. One exception to this protocol should be noted. Helium, used as a tracer gas at one point per site, will be applied by releasing the contents of a 230 cubic foot compressed gas cylinder containing 1.5 percent helium in air.

5.0 BASE SUPPORT REQUIREMENTS

The following base support is needed prior to the arrival of the Engineering-Science test team:

- Confirmation of regulatory approval for the pilot test.
- Provide any paperwork required to obtain gate passes and security badges for approximately three Engineering-Science employees. Vehicle passes will be needed for one truck.

During the initial four week pilot test the following base support is needed:

- Twelve square feet of desk space and a telephone in a building located as near to the site as practical.
- The use of a fax machine for transmitting 15 to 20 pages of test results.

During the one year extended pilot test on the four sites:

- Check the blower systems at the four sites once a week to ensure that it is operating and to record the operating parameters (pressure, vacuum, and temperature). Engineering-Science will provide a brief training session on this procedure.

- Notify Mr. John Ratz, Mr. Doug Downey or Ms. Gail Saxton, Engineering-Science, Inc. Denver (303) 831-8100, or Mr. Jim Williams of the AFCEE, (800) 821-4528, ext 293 if the blower or motor stop working.
- Arrange site access for an Engineering-Science technician to conduct *in situ* respiration tests approximately six months and one year after the initial pilot test.

6.0 PROJECT SCHEDULE

The following schedule is contingent upon timely approval of this pilot test work plan.

Event	**Date**
Begin Pilot Test	30 June 1992
Complete Initial Pilot Test	28 July 1992
Interim Results Report	22 September 1992
Six-month Respiration Test	December 1992
Final Respiration Test	July 1993

7.0 POINTS OF CONTACT

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(303) 831-8100

REFERENCES

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PART II
DRAFT INTERIM RESULTS REPORT
FOR FOUR BIOVENTING SITES
HILL AIR FORCE BASE, UTAH

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September 1992

A7-4-19

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PART II

INTERIM TEST RESULTS

Initial bioventing pilot tests were completed at four sites on Hill Air Force Base (AFB), Utah, during the period of 30 June to 28 July 1992. The purpose of Part II is to describe the results of the initial pilot tests at these sites and to make specific recommendations for extended testing to determine the long-term impact of bioventing on site contaminants. Brief descriptions of the history, geology, and contamination at the four bioventing sites are contained in Part I, the Test Work Plan.

1.0 SITE 204.1

1.1 Pilot Test Design

The following sections describe the final design and installation of the bioventing system on Site 204.1. The vent well and vapor monitoring points at Site 204.1 were installed by another Air Force contractor in May 1992, prior to ES involvement. One vent well and three vapor monitoring points were installed, along with one groundwater monitoring well.

ES installed a single blower unit at Site 204.1. The location of the blower unit was changed slightly from that shown in the test work plan to allow access to the southwest side of Building 207, an area that is currently being used for equipment storage. Figure 1.1 depicts the actual location of the blower unit installed at Site 204.1.

Soils on this site consisted of alternating layers of sand, silty sand, and gravel. Groundwater occurs at a depth of approximately 150 feet below the ground surface (bgs) and is not believed to be affected by fuel contamination from the former USTs.

1.1.1 Air-Injection Vent Well

The air-injection vent well, designated as SB204A-04, was installed by another Air Force contractor following procedures described in the protocol document (Hinchee et.al., 1992). The location of the vent well is illustrated in Figure 1.1, and construction details for the vent well are included in Appendix A. The vent well was constructed using 4-inch diameter polyvinyl chloride (PVC) casing with 40 feet of screen with 0.020-inch slot size installed from 10 to 50 feet bgs. The annular space between the well casing and borehole was filled with 8-12 silica sand. Two feet of

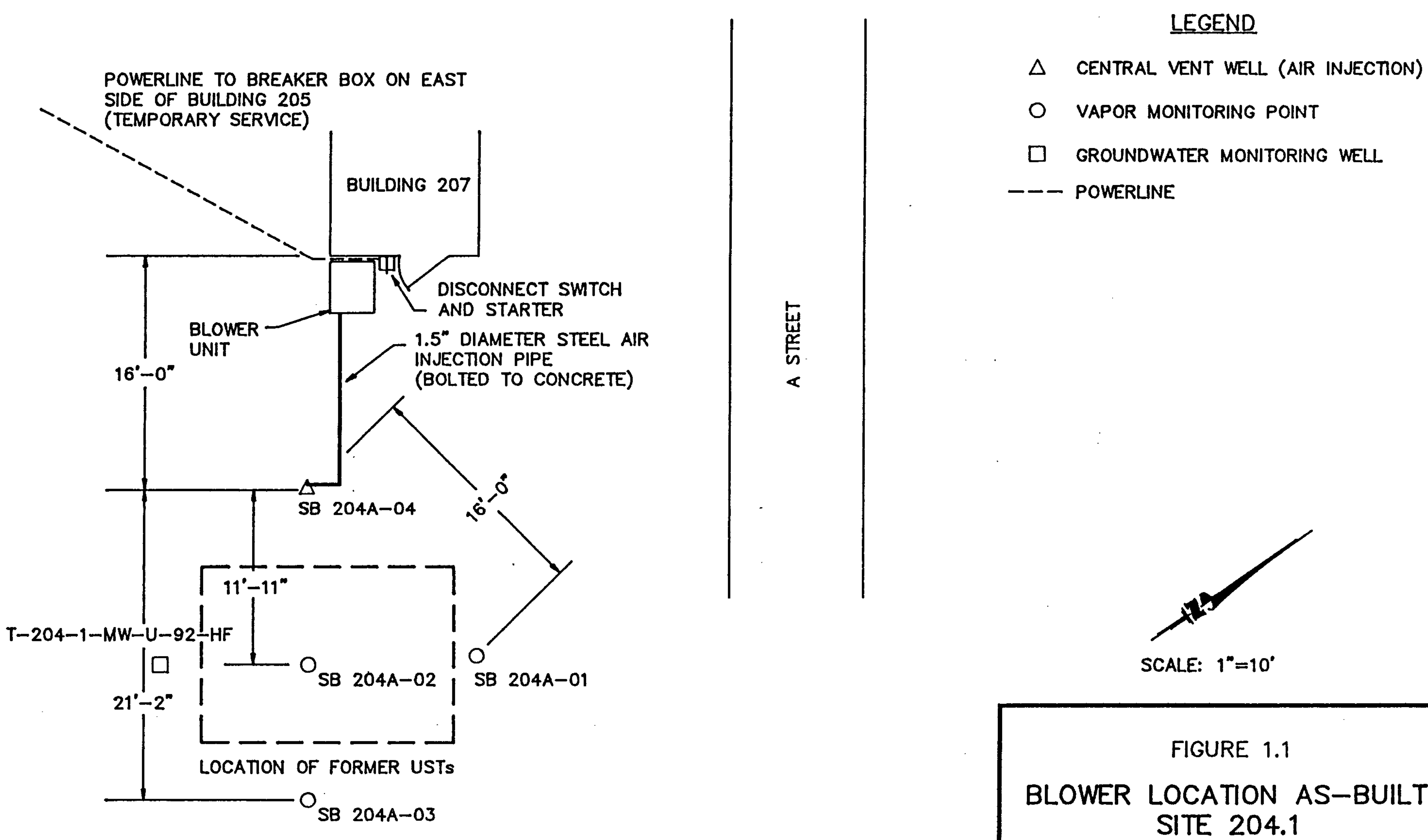

FIGURE 1.1

BLOWER LOCATION AS-BUILT
SITE 204.1

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Denver, Colorado

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bentonite slurry were placed above the sand, followed by a cement grout to the ground surface (Montgomery, July 1992a).

1.1.2 Monitoring Points

The monitoring points were also installed by another Air Force contractor prior to ES involvement. Three monitoring points were constructed at Site 204.1 at locations shown in Figure 1.1. Construction details for the monitoring points are included in Appendix A. Monitoring point SB204A-01 was screened at three different depth intervals: 9 to 10 feet, 27 to 28 feet, and 34 to 35 feet bgs. Monitoring points SB204A-02 and SB204A-03 were screened from 11 to 12 feet bgs and 12 to 13 feet bgs, respectively. Each point was constructed using a 1-foot section of 2-inch diameter PVC well screen with 0.020-inch slot size and 0.25-inch inside diameter rigid plastic tubing extending to the surface. The top of each monitoring point was completed with a flush-mount metal well protector set in a concrete base. Each monitoring point was labeled with metallic tape as described in the protocol document.

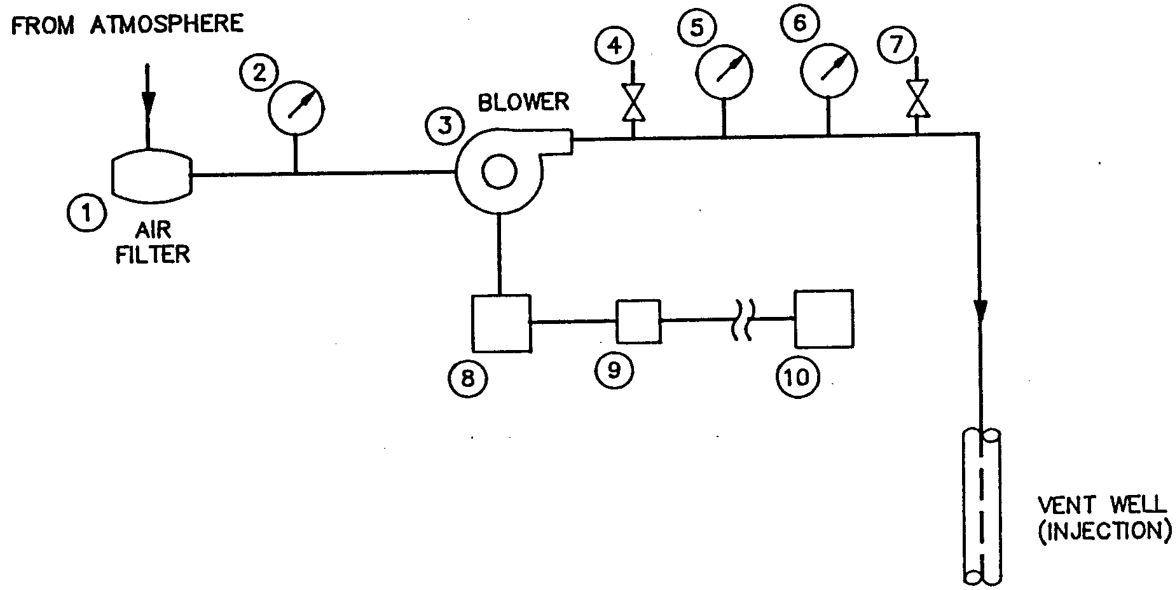
1.1.3 Blower Unit

A 1-horsepower Gast® R4110-2 regenerative blower unit was used at Site 204.1 for both the initial pilot test and the extended pilot test. The blower unit is temporarily energized by 115-volt, single phase, 30-amp line power from a breaker box on the east side of Building 205. Hill AFB electricians will complete permanent electrical hookup when power is restored to Building 207 in Fall 1992. The configuration, instrumentation and specifications for this system are shown on Figure 1.2. The blower is currently operating at 70 scfm with a wellhead pressure of 4 inches H_2O. A portion of the air flow is being released from the system through the bleed valve. The bleed valve is open approximately 1.75 turns to optimize and minimize the volume of air being injected into the soil. By reducing the air injection rate, the subsurface transport of volatile contaminants through the soil gas is minimized and the risk of explosive vapor accumulation in confined spaces is minimized. A copy of the blower operation and maintenance check list provided to the base is found in Appendix B.

1.2 Soil and Soil Gas Sampling Results

Based on a site investigation by James M. Montgomery, Inc. (July 1992a), hydrocarbon contamination appears to extend to a maximum depth of 61 feet bgs and to a lateral extent of 10 feet in all directions from the former UST location. Five soil borings were placed in and around the area of the former USTs to define the extent of contamination. Each borehole was completed as a groundwater monitoring well, air-injection vent well, or a vapor monitoring point (Figure 1.1). Results of laboratory soil sampling are summarized in Table 1.1. Total petroleum hydrocarbon (TPH) detections ranged from 0.2 to 1500 mg/kg.

Laboratory soil gas samples were collected from the monitoring points and the vent well. The monitoring points were purged for 1 minute and the vent well was purged for 20 minutes prior to sample collection using a 1 standard cubic foot per minute (scfm) vacuum pump. Soil gas samples were shipped by Federal Express®



LEGEND

1. INLET AIR FILTER – SOLBERG F-18P-150
2. VACUUM GAUGE (In H_2O)
3. BLOWER – GAST R4110-2
4. AUTOMATIC PRESSURE RELIEF VALVE (SET AT 42 in H_2O)
5. PRESSURE GAUGE (In H_2O)
6. TEMPERATURE GAUGE (°F)
7. MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2" GATE
8. STARTER – FURNAS 14CSE33DA NEMA 3
9. DISCONNECT SWITCH
10. BREAKER BOX

FIGURE 1.2

AS-BUILT BLOWER SYSTEM FOR AIR INJECTION SITE 204.1

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TABLE 1.1
SITE 204.1
SOIL AND SOIL GAS ANALYTICAL RESULTS

Analyte (Units) a/	Sample Location (feet bgs)		
Soil Hydrocarbons b/	SB204A-01 (9-9.5)	SB204A-02 (11-11.5)	SB204A-04 (12.5-13)
TPH (mg/kg)	370	1000	1500
Benzene (mg/kg)	0.009	0.031	0.023
Toluene (mg/kg)	<0.005	0.22	0.26
Ethylbenzene (mg/kg)	0.047	0.8	0.78
Xylenes (mg/kg)	0.19	7.7	7.4
Soil Gas Hydrocarbons	SB204A-01 (34-35)	SB204A-02 (11-12)	SB204A-04 (10-50)
TPH (ppmv) c/	7.5	160	490
Benzene (ppmv)	0.01	0.053	0.016
Toluene (ppmv)	0.006	0.06	0.25
Ethylbenzene (ppmv)	ND d/	0.085	0.17
Xylenes (ppmv)	ND	0.31	0.85
Soil Physical Parameters b/	SB204A-01 (20-20.5)	SB204A-01 (40.5-41)	T-204-1-MW-92-HF (60.5-61)
Moisture (% wt.)	5.1	4.4	4.5
Gravel (%)	34	6	3
Sand (%)	60	84.5	91
Silt (%)	3	4.5	3
Clay (%)	3	5	3

a/ mg/kg=milligrams per kilogram; ppmv=parts per million, volume per volume.
b/ Montgomery, July 1992a.
c/ TPH referenced to Jet Fuel (molecular weight=156).
d/ ND = Not detected.

to Air Toxics Inc. in Rancho Cordova, California, for TPH (referenced to JP-4 jet fuel) and benzene, toluene, ethylbenzene, and total xylenes (BTEX) analyses by Method TO-3. The results of these analyses are provided in Table 1.1.

1.3 Exceptions To Test Protocol

Procedures contained in the protocol were used to complete treatability tests at Site 204.1. Due to the delayed shipment of the blower unit, the sequence of *in situ* respiration testing and soil gas permeability testing had to be reversed. Although the respiration test was performed first, enough time was provided for the soil gas to return to initial conditions prior to the start of the air permeability test.

Helium injection prior to *in situ* respiration testing was performed using an alternative method to that described in the protocol document. To improve the consistency of injected helium concentrations, air and helium were injected by metering in a premixed 230 cubic feet cylinder of 1.5 percent helium and 98.5 percent air. At Site 204.1, the contents of this cylinder were injected over an approximate 10 hour interval at a flow of approximately 0.4 scfm. The advantage of this method is that a uniform helium concentration can be injected with minimum oversight. The disadvantage of this method is that several cylinders of premixed gas may be required to reduce the diffusion effects around the monitoring point. The cost and inconvenience of handling four to six large cylinders at each site may not be acceptable. Additionally, a constant flow rate could not be attained using the single-valve pressure regulators. ES will continue to refine and test helium injection techniques and make a recommendation to AFCEE at a future date.

1.4 Test Results

1.4.1 Initial Soil Gas Chemistry

On 2 July 1992, soil gas from all monitoring points and the vent well at Site 204.1 was sampled to determine initial oxygen, carbon dioxide and TVH concentrations. The vent well was purged for 20 minutes and the monitoring points were purged for 1 minute prior to sampling using a 1-scfm vacuum pump. These purge times were also used throughout respiration and permeability testing. The samples were analyzed in the field using portable gas analyzers, as described in the protocol. Table 1.2 summarizes the initial soil gas chemistry at Site 204.1. SB204A-02 was entirely oxygen depleted. Other monitoring points contained low levels of oxygen, indicating that biological fuel degradation was occurring but oxygen diffusion rates were high enough to prevent the points from becoming anaerobic.

1.4.2 Soil Gas Permeability

A soil gas permeability test was conducted according to protocol procedures. Air was injected into the vent well (SB204A-04) at a rate of approximately 77 scfm and an average pressure of approximately 10 inches H_2O. The pressure response at each monitoring point is recorded in Table 1.3. Due to the rapid response and relatively short time to steady state conditions, the steady state method of determining soil gas permeability was selected. As discussed in the protocol, the dynamic method of determining soil gas permeability that is coded in the Hyperventilate® model is not appropriate for soils which reach steady state in less than 10 minutes. Using the

TABLE 1.2
SITE 204.1
INITIAL SOIL GAS CHEMISTRY

Monitoring Point	Depth (ft bgs)	O2(%)	CO2(%)	TVH(ppmv)
SB204A-01	9-10	12.8	8.1	72
SB204A-01	27-28	13	6.5	120
SB204A-01	34-35	6.7	10.2	110
SB204A-02	11-12	0.2	17	580
SB204A-03	12-13	9.2	9.3	84
SB204A-04	10-50	8.2	9.4	880

TABLE 1.3
SITE 204.1
PRESSURE RESPONSE AT MONITORING POINTS
DURING THE AIR PERMEABILITY TEST

Monitoring Point (feet bgs)	SB204A-01 (9-10)	SB204A-01 (27-28)	SB204A-01 (34-35)	SB204A-02 (11-12)	SB204A-03 (12-13)
Elapsed Time (minutes)	Pressure Response, inches of water.				
0					
1	0.2	0.5	0.35	NS	NS
2	NS	NS	NS	NS	0.4
3	0.5	0.65	0.45	0.8	NS
5	NS	NS	NS	NS	0.5
6	NS	NS	NS	0.9	NS
7	0.55	0.75	0.6	NS	NS
8	NS	NS	NS	0.95	0.5
9	0.55	0.75	0.6	NS	NS
10	NS	NS	NS	0.95	0.55
11	0.6	0.8	0.65	NS	NS
12	NS	NS	NS	0.95	0.55
13	0.65	0.8	0.65	NS	NS
14	NS	NS	NS	0.95	0.6
15	0.65	0.85	0.7	NS	NS
16	NS	NS	NS	0.95	0.6
17	0.65	0.85	0.65	NS	NS
18	NS	NS	NS	0.95	0.6
19	0.65	0.9	0.75	NS	NS
20	NS	NS	NS	1	0.65
22	0.7	0.85	0.65	NS	NS
24	NS	NS	NS	1	0.65
28	0.7	0.9	0.75	NS	NS
29	NS	NS	NS	1	0.65
34	0.65	0.9	0.75	NS	NS
36	NS	NS	NS	1	0.65
42	0.7	0.8	0.8	NS	NS
44	NS	NS	NS	1	0.65
52	0.7	0.9	0.8	NS	NS
64	0.7	0.9	0.75	NS	NS
65	NS	NS	NS	1.05	0.65
82	0.7	0.95	0.8	1.05	0.7
107	0.65	0.9	0.8	1.05	0.65
129	0.7	0.9	0.8	1.05	0.65
178	0.7	0.9	0.8	1.05	0.65
190	NS	NS	NS	1.05	0.65
213	0.65	0.9	0.75	1.05	0.65
249	0.65	0.9	0.75	1.05	0.65
1186	0.55	0.7	0.55	0.9	0.55

NS = Not sampled.

steady state method, a soil gas permeability value of 18.9 darcies was calculated for the site soils. A radius of pressure influence of approximately 60 feet was observed.

1.4.3 Oxygen Influence

The depth and radius of oxygen increase in the subsurface resulting from air injection in the central vent well is the primary design parameter for bioventing systems. Optimization of full-scale and multiple vent well systems requires pilot testing to determine the volume of soil which can be oxygenated at a given flow rate and vent well screen configuration.

Table 1.4 describes the change in soil gas oxygen levels that occurred during 20 hours of air injection into the Site 204.1 vent well (SB204A-04) at an average flow rate of 77 scfm. Oxygen levels increased significantly in all locations, except for monitoring point SB204A-01 at a depth of 9 to 10 feet bgs. At this shallow monitoring point on the eastern edge of the contaminated zone, oxygen was already present at high levels (17.2 percent) prior to the start of air injection. This relatively brief air injection of 77 scfm produced a radius of oxygen influence of at least 21 feet in site soils. It is our opinion that the radius of oxygen influence for a long-term bioventing system on this site will exceed 21 feet at all depths, and that the entire contaminated region is being supplied with oxygen. Future monitoring at this site will better define the treatment radius.

1.4.4 In Situ Respiration Rates

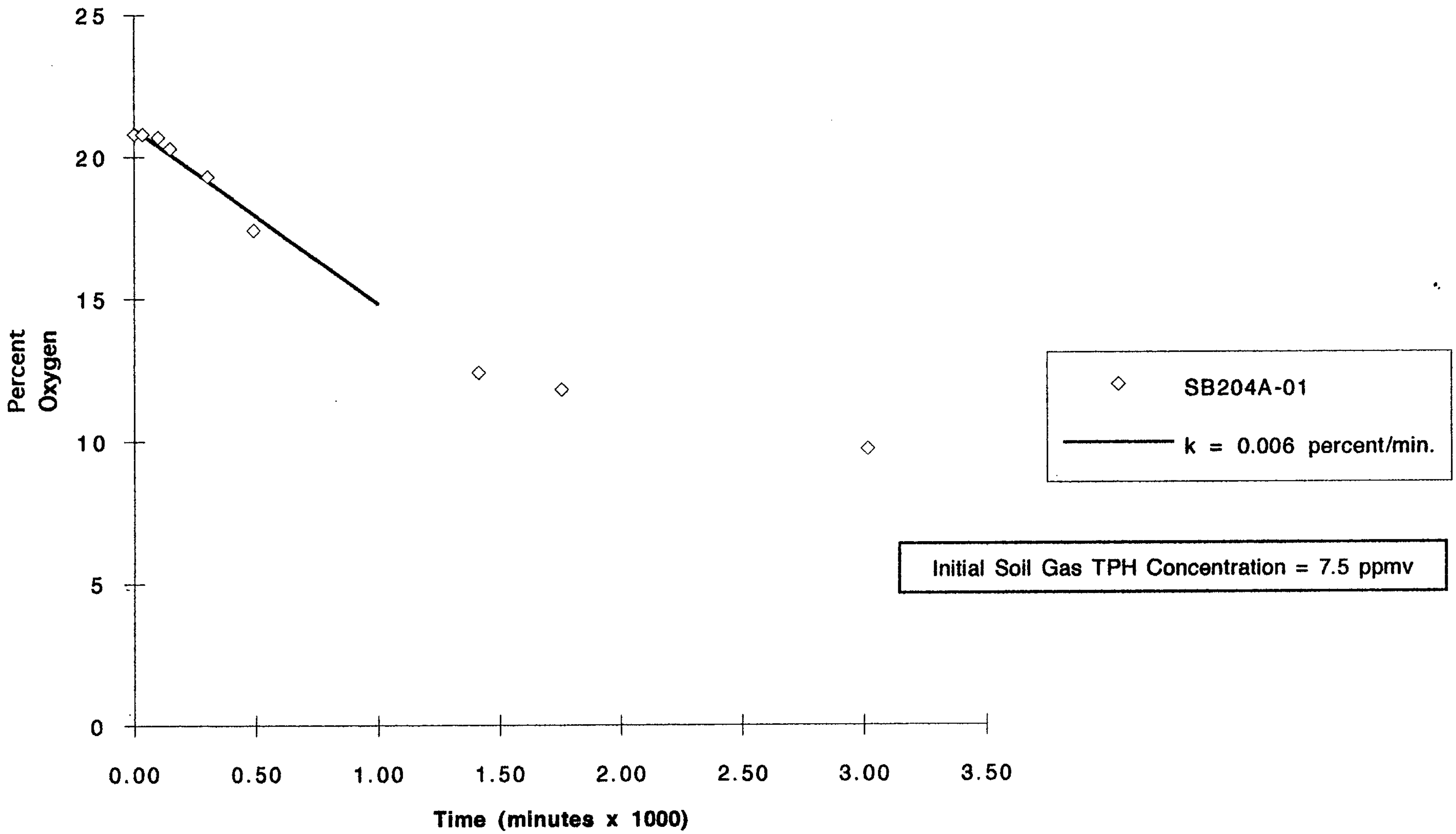
The results of *in situ* respiration testing at Site 204.1 are presented in Figures 1.3 through 1.5. Oxygen loss at SB204A-01 occurred at a slow, steady rate of .006 percent/minute over the first 500 minutes of the respiration test (Figure 1.3). In comparison, oxygen loss was rapid at SB204A-02 and SB204A-04 (Figures 1.4 and 1.5). During the first 500 minutes, oxygen was lost from monitoring point SB204A-02 at a rate of .017 percent/minute, and from vent well SB204A-04 at a rate of .026 percent/minute. The difference in oxygen utilization rates is caused by differing contaminant concentrations at each location. At SB204A-01 (34-35 feet bgs), the initial laboratory TPH concentration was 7.5 ppmv (Table 1.1). In contrast, initial laboratory TPH concentrations for SB204A-02 and SB204A-04 were 160 ppmv and 490 ppmv, respectively. Since less fuel is available at SB204A-01 than at SB204A-02 and SB204A-04, fuel biodegration rates are slower.

During the initial 500 minutes of the *in situ* respiration test, helium diffusion at SB204A-02 resulted in a fractional loss of approximately 35 percent of the initial helium concentration (Figure 1.6). Due to its greater molecular weight, oxygen will diffuse approximately three times slower than helium. This means that at SB204A-02, approximately 12 percent of the initial oxygen may have been lost due to diffusion during the initial 500 minutes. Table 1.5 provides a summary of the observed and corrected oxygen utilization rates for Site 204.1. Since these monitoring points were completed in generally uniform soils, oxygen diffusion rates for SB204A-01 and SB204A-04 were assumed to be similar to the rate estimated for SB204A-02. It is interesting to note that at SB204A-02 and SB204A-04, almost all of the oxygen loss was attributed to biodegradation.

TABLE 1.4
SITE 204.1
INFLUENCE OF AIR INJECTION AT VENT WELL
ON MONITORING POINT OXYGEN LEVELS

Monitoring Point	Distance From Vent Well (ft)	Depth (feet bgs)	Initial O2(%)	Final O2(%)
SB204A-01	16	9-10	17.2	15.2
SB204A-01	16	27-28	12.4	20.3
SB204A-01	16	34-35	10.1	19.1
SB204A-02	11.92	11-12	4.2	17
SB204A-03	21.17	12-13	9	16.5

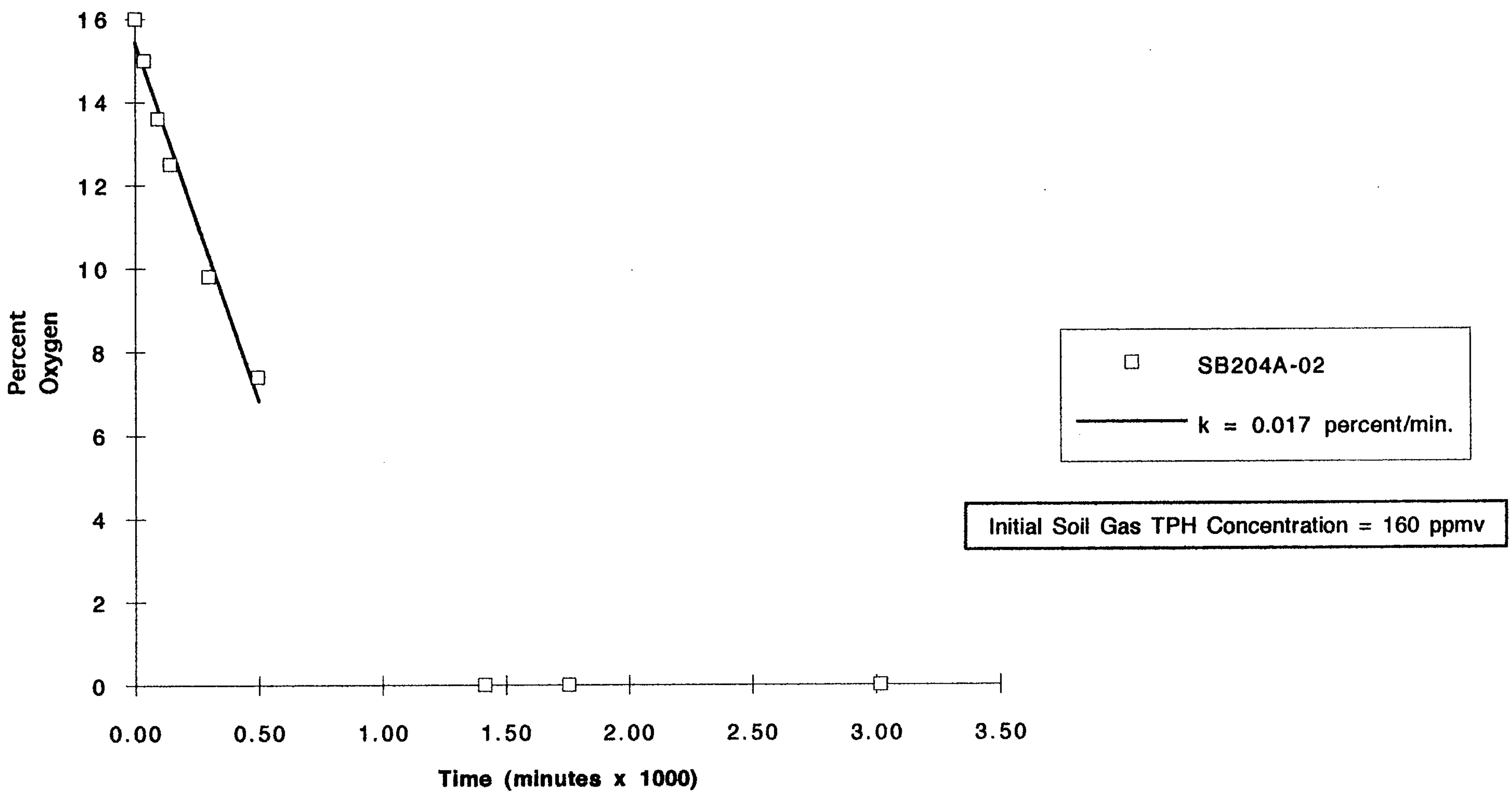
Figure 1.3
Respiration Test at SB204A-01 (34-35 feet bgs)
Site 204.1 - Hill AFB, Utah



R. T. Site 204 VW204A-01

9/17/92

Figure 1.4
Respiration Test at SB204A-02
Site 204.1 - Hill AFB, Utah



R. T. Site 204 VW204A-02

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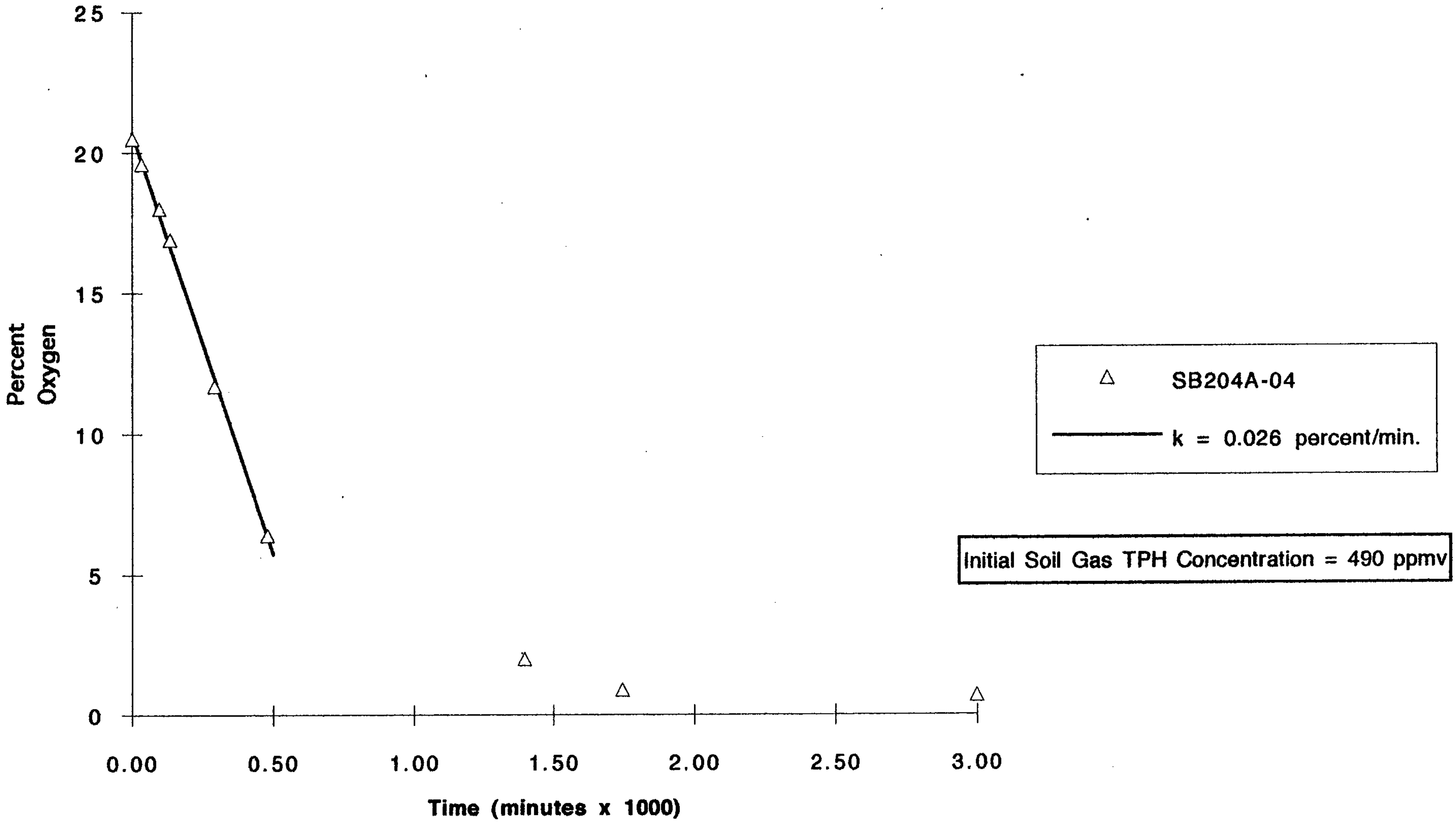
Figure 1.5
Respiration Test at SB204A-04
Site 204.1 - Hill AFB, Utah



R. T. Site 204 VW204A-04

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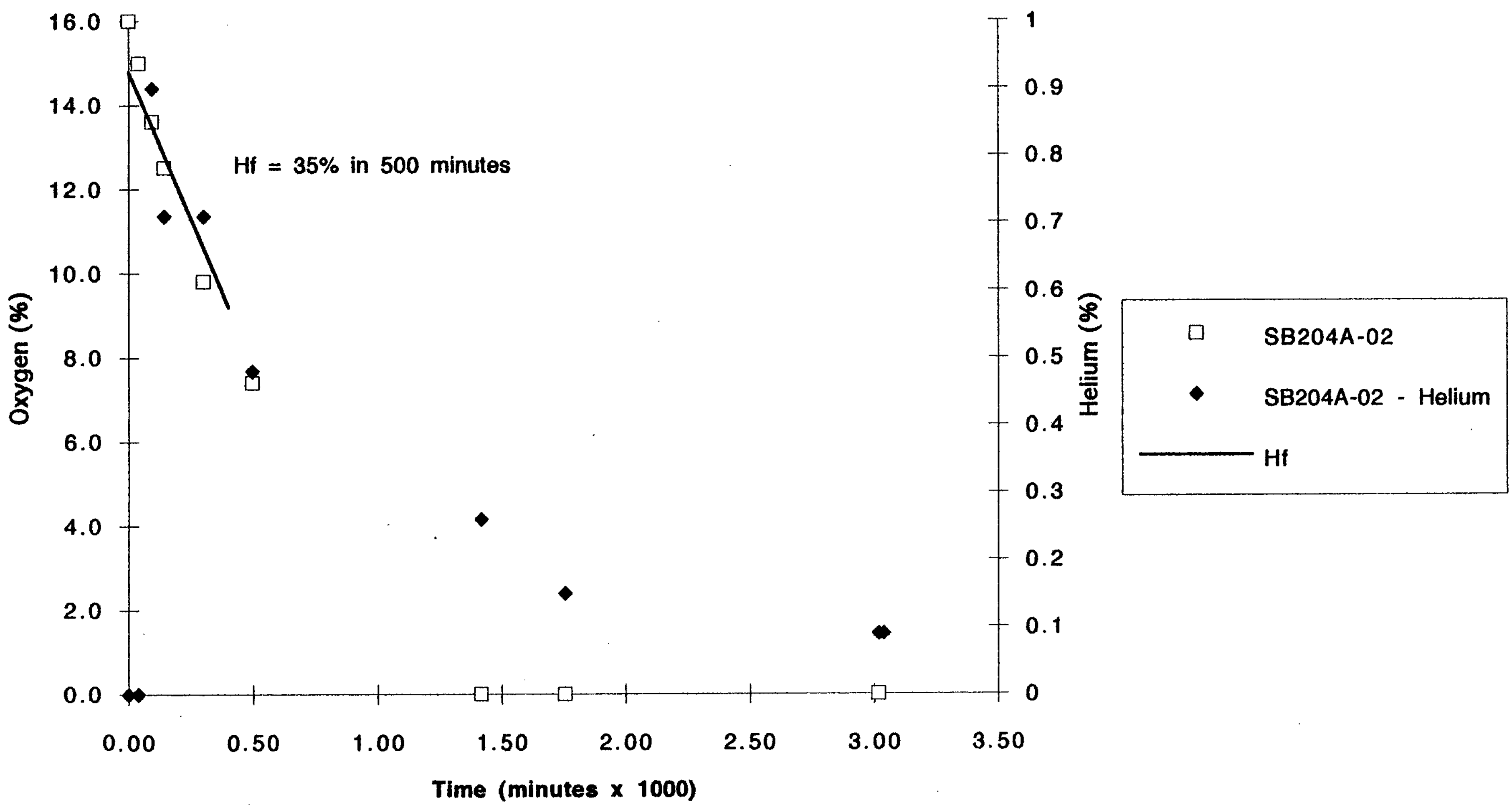
Figure 1.6
Respiration Test
Oxygen/Helium Concentrations
Monitoring Point SB204A-02
Site 204.1 - Hill AFB, Utah



O2/Helium 204A-02

8/17/92

TABLE 1.5

APPARENT AND CORRECTED OXYGEN UTILIZATION RATES (0-500 MINUTES)

	Apparent O_2 loss (%/min)	Fractional Helium Loss (%)	Fractional O_2 Diffusion (%)	Estimated O_2 Diffusion (%/min)	Corrected O_2 Utilization (%/min)
SB204A-01	.006	35**	12**	.002	.004
SB204A-02	.017	35	12	.002	.015
SB204A-04(Vent Well)	.026	35**	12**	.002	.024

** Based on helium diffusion from SB204A-02.

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Based on the oxygen utilization rates observed at SB204A-01, SB204A-02, and SB204A-04 during the initial 500 minutes, an estimated 12.6 milligrams of fuel per kilogram of soil can be degraded each day on this site. This estimate is based on an average air-filled porosity of .16 liters per kilogram of soil and a conservative ratio of 3.5 milligrams of oxygen consumed for every 1 milligram of fuel degraded.

The apparent decrease in oxygen utilization rate over time at SB204A-01 and SB204A-04 has been observed by ES at other fuel spill sites where contamination levels and soil types are variable. Table 1.2 provided initial oxygen levels at the vent well and monitoring points and clearly illustrates this variability. The protocol model for helium and oxygen diffusion assumes that each monitoring point is surrounded by contaminated soil with zero oxygen and that the gradient of oxygen diffusion is always outward from the monitoring point. It is apparent that at Site 204.1, clean, oxygenated soil is in close proximity to a relatively small zone of contaminated, zero oxygen soil. In this situation, we believe that the oxygen gradient actually reverses over time. As oxygen is rapidly consumed by fuel degrading bacteria the inward diffusion of oxygen begins from clean soils. The effect of this inward diffusion is an apparent reduction in oxygen utilization rates over time. Because fuel-degrading bacteria generally consume oxygen at a rate that exceeds diffusion, soil gas eventually returns to zero in contaminated soil.

1.5 Recommendations

Initial bioventing tests on this site indicate that oxygen has been depleted in contaminated soils and that air injection is an effective method of increasing aerobic fuel biodegradation. AFCEE has recommended that air injection continue on this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients and changing temperatures on fuel biodegradation rates.

A small regenerative blower has been installed on the site (Figure 1.1) to continue a low rate of air injection. In December of 1992, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. To improve respiration test results, a longer period of air injection will be used to more evenly distribute oxygen and helium. In July of 1993, a final respiration test will be completed and soil and soil gas samples collected from the site to determine the degree of remediation achieved during the first year.

Based on the results of the first year of bioventing, AFCEE will recommend one of three options:

1. Continued operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the base in obtaining regulatory approval for upgrade and continued operation.

2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that clean up criteria have been achieved.

3. If significant difficulties or poor results are encountered within bioventing on this site, AFCEE could recommend the removal of the blower system and proper abandonment of the vent well.

2.0 SITE 214.1

2.1 Pilot Test Design

The following sections describe the final design and installation of the bioventing system on Site 214.1. The vent well and vapor monitoring points at Site 214.1 were installed by another Air Force contractor in October and November 1991, prior to ES involvement. One vent well and two vapor monitoring points were installed, along with one groundwater monitoring well.

ES installed a single blower unit at Site 214.1 at the location shown in the test work plan. Figure 2.1 depicts the actual location of the blower unit installed at Site 214.1.

Soils on this site consisted of alternating layers of sand, silty sand, and gravel. Groundwater occurs at a depth of approximately 150 feet bgs and is not believed to be affected by solvent contamination from the former UST.

2.1.1 Air-Extraction Vent Well

The air-extraction vent well, designated as SB214A-01, was installed by another Air Force contractor following procedures described in the protocol document (Hinchee et.al., 1992). The location of the vent well is illustrated in Figure 2.1, and construction details for the vent well can be found in Appendix A. The vent well was constructed using 4-inch diameter PVC casing with 55 feet of screen with 0.010-inch slot size installed from 5 to 60 feet bgs. The annular space between the well casing and borehole was filled with 10-20 silica sand. Three feet of bentonite slurry were placed above the sand, followed by a cement-bentonite grout to the ground surface (Montgomery, December, 1991a).

The configuration of the well screen complicated *in situ* respiration testing, and will reduce the efficiency of the bioventing system. Although the vent well is screened to a depth of 60 feet bgs, hydrocarbon contamination appeared to be limited to the upper 43 feet of the soil column. Thus, the extraction system will provide soil gas flow through a non-contaminated soil zone 43 to 60 feet bgs, a zone that does not need to be oxygenated. Soil gas samples collected from the vent well were high in oxygen content. The oxygen in these samples likely originated in deeper non-contaminated soils and may have masked oxygen consumption in the upper contaminated layer, had a respiration test been performed at the vent well. In an attempt to overcome this testing problem, a new soil gas probe, designated as MP1, was installed and used rather than the vent well to conduct *in situ* respiration testing.

2.1.2 Monitoring Points

The monitoring points at Site 214.1 were also installed in October and November 1991 by another Air Force subcontractor prior to ES involvement. Each point was constructed using 0.25-inch flexible Latex® or rubber tubing. Soil gas could not be extracted from the monitoring points at any time during the initial pilot test. It is likely that the tubing had been squeezed shut by the weight of the sand pack. Therefore, soil gas monitoring could only be conducted using a temporary soil gas

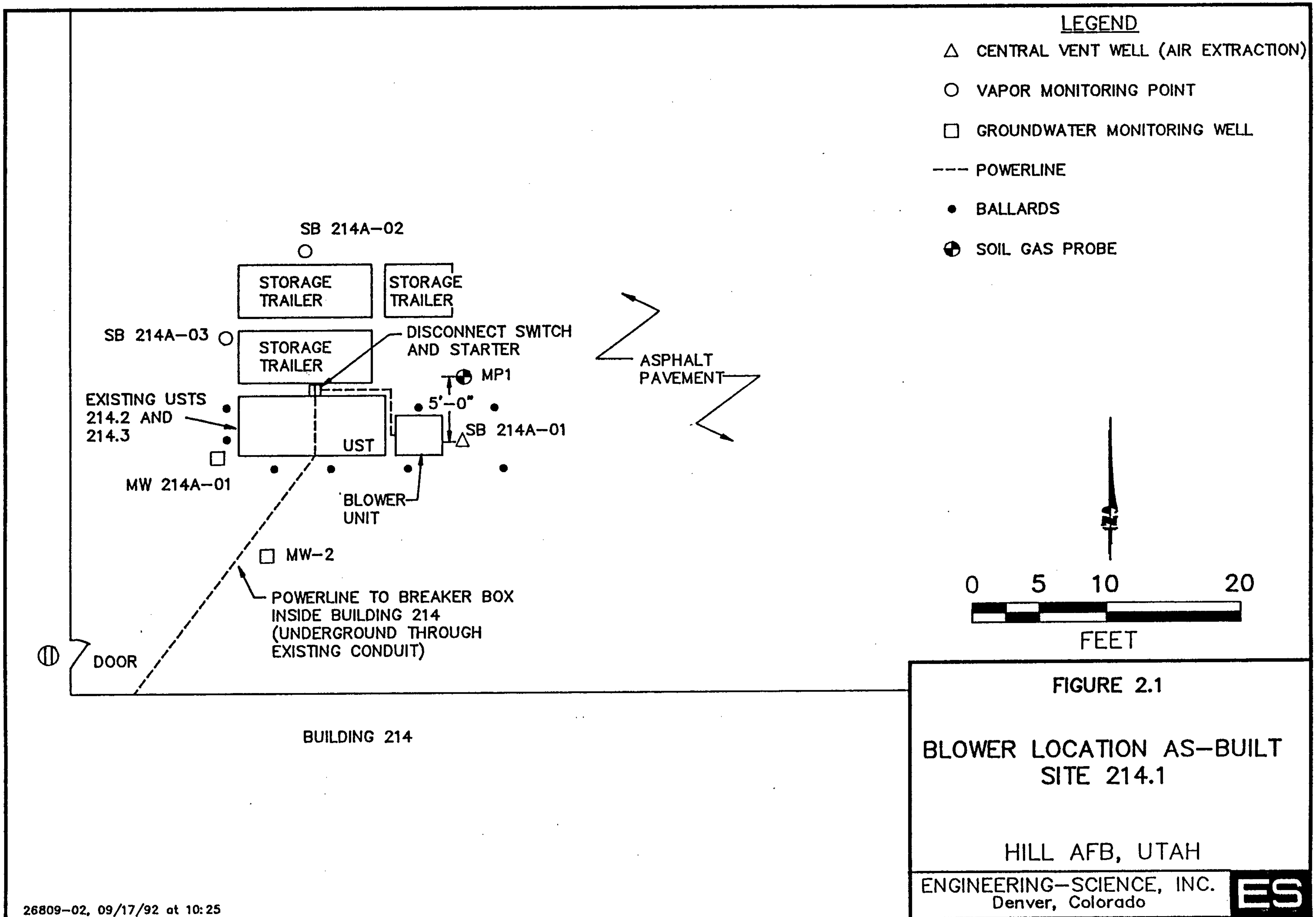


FIGURE 2.1

BLOWER LOCATION AS-BUILT
SITE 214.1

HILL AFB, UTAH

probe. Probe MP1 was driven to a depth of twelve feet at a location five feet north of the vent well (Figure 2.1).

2.1.3 Blower Unit

A 1-horsepower Gast® R4110-2 regenerative blower unit was used at Site 214.1 for both the initial pilot test and the extended pilot test. An air extraction system was recommended by ES to prevent the possible movement of hydrocarbon vapors into Building 214. As levels of soil gas hydrocarbon vapors decrease on the site, a switch to an air injection system is anticipated. The blower unit is energized by 115-volt, single phase, 30-amp line power from a breaker box inside Building 214. The blower is not currently operating, pending the completion of an air permit to allow the short-term extraction of hydrocarbon vapors. The configuration, instrumentation and specifications for this system are shown on Figure 2.2. A copy of the blower operation and maintenance checklist provided to the base is found in Appendix B.

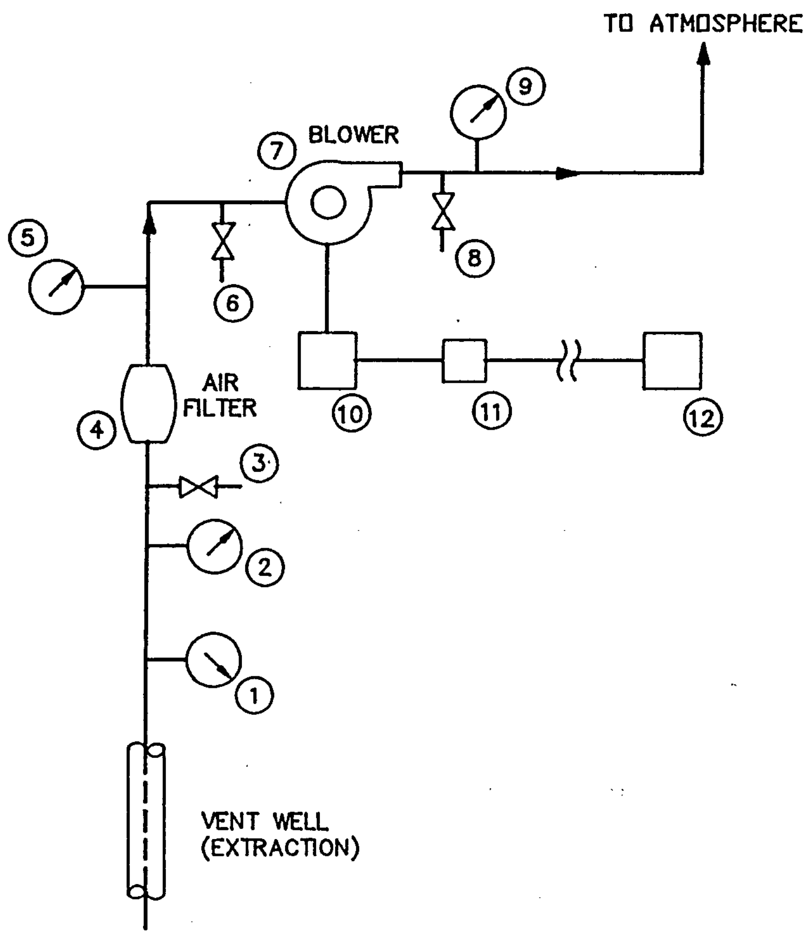
2.2 Soil and Soil Gas Sampling Results

Based on a previous site investigation (Montgomery, December 1991a and July 1992b), hydrocarbon contamination appears to be limited to an area immediately surrounding the UST. Soil borings were placed on all four sides of the current UST at distances from 5 to 20 feet from the tank. The only boring where hydrocarbon contamination was detected was SB214A-01, the location of the vent well. At this location, a laboratory soil sample collected from 11 to 12 feet was the only sample with measurable contamination. TPH was detected at a concentration of 36,200 mg/kg, while BTEX compounds were also detected at elevated concentrations (Table 2.1). Based on field headspace measurements, the vertical extent of vapor contamination appeared to be 43 feet bgs. The laboratory results of a soil sample from 44 to 45 feet bgs showed no detectable contamination (Montgomery, December 1991a).

Laboratory soil gas samples were collected from the soil gas probe MP1, vent well SB214A-01, and the blower unit exhaust. The probe was purged for 1 minute and the vent well was purged for 20 minutes using a 1-scfm vacuum pump prior to sample collection. Soil gas samples were shipped by Federal Express® to Air Toxics, Inc. in Rancho Cordova, California, for TPH (referenced to JP-4 jet fuel) and BTEX analyses by Method TO-3. The results of these analyses are provided in Table 2.1.

2.3 Exceptions To Test Protocol

Procedures described in the protocol document were used to complete the treatability tests at Site 214.1. Since initial oxygen levels on this site were not depleted in the vent well, the value of *in situ* respiration and helium diffusion data was questionable. Therefore, no helium injection was performed at this site. Site 214.1 is only between 200 and 300 feet southwest of Site 204.1, and the soil characteristics at these two sites are similar. Therefore, helium data obtained at Site 204.1 was deemed sufficient to define diffusion rates at Site 214.1. Because the existing monitoring points could not be used to extract soil gas samples, one soil gas



LEGEND

1. VACUUM GAUGE (In H_2O)
2. TEMPERATURE GAUGE (°F)
3. MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2" GATE
4. INLINE AIR FILTER – SOLBERG F–18P–150
5. VACUUM GAUGE (In H_2O)
6. AUTOMATIC PRESSURE RELIEF VALVE (SET AT 42 in H_2O)
7. BLOWER – GAST R4110–2
8. SAMPLING PORT
9. PRESSURE GAUGE (In H_2O)
10. STARTER – FURNAS 14CSE33DA NEMA 3
11. DISCONNECT SWITCH
12. BREAKER BOX

FIGURE 2.2

AS–BUILT BLOWER SYSTEM FOR AIR EXTRACTION SITE 214.1

HILL AFB, UTAH

ENGINEERING–SCIENCE, INC.
Denver, Colorado

26809–06, 09/14/92 at 15:11

TABLE 2.1
SITE 214.1
SOIL AND SOIL GAS ANALYTICAL RESULTS

Analyte (Units) a/	Sample Location (feet bgs)		
Soil Hydrocarbons b/	**SB214A-01 (11-12)**	**SB214A-01 (44-45)**	**SB214A-01 (57-58)**
TPH (mg/kg)	36200	<10	<10
Benzene (mg/kg)	<50	<10	<10
Toluene (mg/kg)	1150	<10	<10
Ethylbenzene (mg/kg)	5840	<10	<10
Xylenes (mg/kg)	17300	<10	<10
Soil Gas Hydrocarbons	**SB214A-01 (5-60)**	**MP1 (12)**	**VW-EXH c/**
TPH (ppmv) d/	960	8.1	840
Benzene (ppmv)	0.019	ND e/	0.006
Toluene (ppmv)	0.076	ND	0.2
Ethylbenzene (ppmv)	0.52	ND	0.11
Xylenes (ppmv)	0.51	ND	0.23
Soil Physical Parameters b/	**SB214A-01 (20)**	**SB214A-01 (40.5)**	
Moisture (% wt.)	7.5	9.9	
Gravel (%)	39	0	
Sand (%)	51	65.5	
Silt (%)	6.5	25.5	
Clay (%)	3.5	9	

a/ mg/kg=milligrams per kilogram; ppmv=parts per million, volume per volume.
b/ Montgomery, December 1991a.
c/ Sample of the well exhaust, collected on 23 July 1992.
d/ TPH referenced to Jet Fuel (molecular weight=156).
e/ ND=Not detected.

probe, designated as MP1, was used in respiration and permeability testing. The probe was set at a depth of 12 feet bgs for both tests.

The sequence of *in situ* respiration testing and soil gas permeability testing was reversed due to the delayed shipment of the blower unit. Although the respiration test was performed first, enough time was allowed for soil gas to return to initial conditions before the start of the soil gas permeability test.

2.4 Test Results

2.4.1 Initial Soil Gas Chemistry

Prior to the initiation of air injection or extraction at Site 214.1, the vent well and the soil gas probe were sampled to determine initial oxygen, carbon dioxide, and TVH concentrations in the soil gas. The vent well was sampled on 7 July 1992 and was purged for twenty minutes prior to sampling. The soil gas probe was sampled on 14 July 1992. The probe was purged for one minute prior to the collection of each sample, and soil gas samples were collected at depths of 6, 9, and 12 feet bgs as the probe was being driven into position. Samples were analyzed using portable soil gas analyzers described in the protocol document. Table 2.2 summarizes the initial soil gas chemistry at Site 214.1. The oxygen concentration of 8.7 percent at the vent well is representative of oxygen levels throughout the vent well screened interval of 5 feet to 60 feet bgs. The depth of contamination is limited to 43 feet bgs. The oxygen in the vent well sample is suspected to come mainly from deeper, non-contaminated soils. At the soil gas probe, the sample from six feet bgs has an oxygen content of 13.2 percent, possibly indicating that soil at this depth is above the contaminated zone. Oxygen was detected at 3.5 percent and 5 percent at depths of 9 and 12 feet bgs, respectively. This seems to indicate that soils at these depths are contaminated and that biological activity is occurring, but oxygen is diffusing in from nearby non-contaminated soils at rates high enough to prevent complete oxygen depletion. It is possible that anaerobic zones exist at Site 214.1 in soil near the center of the contaminated zone. However, there are insufficient soil gas monitoring points on the site to pinpoint the anaerobic soil volume.

2.4.2 Soil Gas Permeability

A soil gas permeability test was conducted according to protocol procedures. Air was extracted at a rate of approximately 71 scfm and an average well head vacuum of approximately 8 inches H_2O. The vacuum response at the soil gas probe is recorded in Table 2.3. Due to the rapid response and relatively short time to steady state conditions, the steady state method of determining soil gas permeability was selected. As discussed in the protocol document, the dynamic method of determining soil gas permeability that is coded in the Hyperventilate® model is not appropriate for soils which reach steady state in less than 10 minutes. Using the steady state method, a soil gas permeability value of 10-20 darcies is estimated for the site soils. A radius of pressure influence and a site-specific darcy value could not be calculated because pressure response could only be measured at MP1.

TABLE 2.2
SITE 214.1
INITIAL SOIL GAS CHEMISTRY

Monitoring Point	Depth (ft bgs)	O2 (%)	CO2 (%)	TVH (ppmv)
SB214A-01	5-60	8.7	9.4	200
MP1	6	13.2	6.5	76
MP1	9	3.5	14.5	130
MP1	12	5	12.7	240

TABLE 2.3
SITE 214.1
VACUUM RESPONSE
AIR PERMEABILITY TEST

Elapsed Time (min)	Vacuum Response at MP1, 12 ft bgs (inches of water)
1	0.6
3	0.82
4	0.9
5	0.95
6	0.95
7	1
9	1.1
10	1.1
11	1.12
12	1.1
18	1.17
23	1.16
31	1.1
41	1.17
52	1.1
60	1.21
110	1.1
246	1.15
1346	1.3
1741	1.3

2.4.3 Oxygen Influence

The depth and radius of oxygen increase in the subsurface resulting from air extraction in the central vent well is the primary design parameter for bioventing systems. Optimization of full-scale and multiple vent well systems requires pilot testing to determine the volume of soil which can be oxygenated at a given flow rate and vent well screen configuration.

Table 2.4 describes the change in soil gas oxygen levels that occurred during a 22 hour air extraction period at the Site 214.1 vent well. This relatively brief air extraction of 71 scfm produced significant oxygen increases at soil gas probe MP1, and in the vent well exhaust. Since the monitoring points could not be used, it was not possible to observe changes in soil gas oxygen levels at greater distances from the vent well.

2.4.4 In Situ Respiration Rates

In situ respiration testing was performed at soil gas probe MP1 located 5 feet north of the vent well. The soil gas probe was driven to a total depth of 12 feet bgs, which corresponds to the depth at which the highest laboratory soil TPH concentration had been detected. A respiration test was not conducted at the vent well, as oxygen from deeper, non-contaminated soils may have masked oxygen consumption occurring in shallow contaminated soils.

The results of *in situ* respiration testing at Site 214.1 are presented in Figure 2.3. Oxygen loss at MP1 was linear with time, and occurred at a rate of 0.005 percent/minute. Because helium injection was not performed at Site 214.1, diffusion rates measured at Site 204.1 were used. Table 2.5 provides a summary of the observed and corrected oxygen utilization rates for Site 214.1.

Based on the oxygen utilization rates observed at soil gas probe MP1 and the soil moisture content at SB214A-01 from 11 to 12 feet bgs, an estimated 0.35 milligrams of hydrocarbon solvent per kilogram of soil can be degraded each day on this site. This estimate is based on a conservative ratio of 3.5 milligrams of oxygen consumed for every 1 milligram of solvent degraded. The soil moisture content had a significant impact on the air-filled porosity of the soil and the estimated solvent degradation rate at MP1. The soil moisture content from 11 to 12 feet bgs at the vent well was 19.0 percent, and the estimated air-filled porosity was only .04 liters air/liters soil. At other locations, soil moisture typically ranged from 5 to 10 percent. Also, the solvent biodegradation rate is conservative because MP1 was not completed in highly contaminated soil. The laboratory soil gas TPH concentration at MP1 was 8.1 ppmv, as compared to 960 ppmv of TPH at the vent well (Table 2.1). Biodegradation rates will typically be higher in more heavily contaminated soils.

2.5 Recommendations

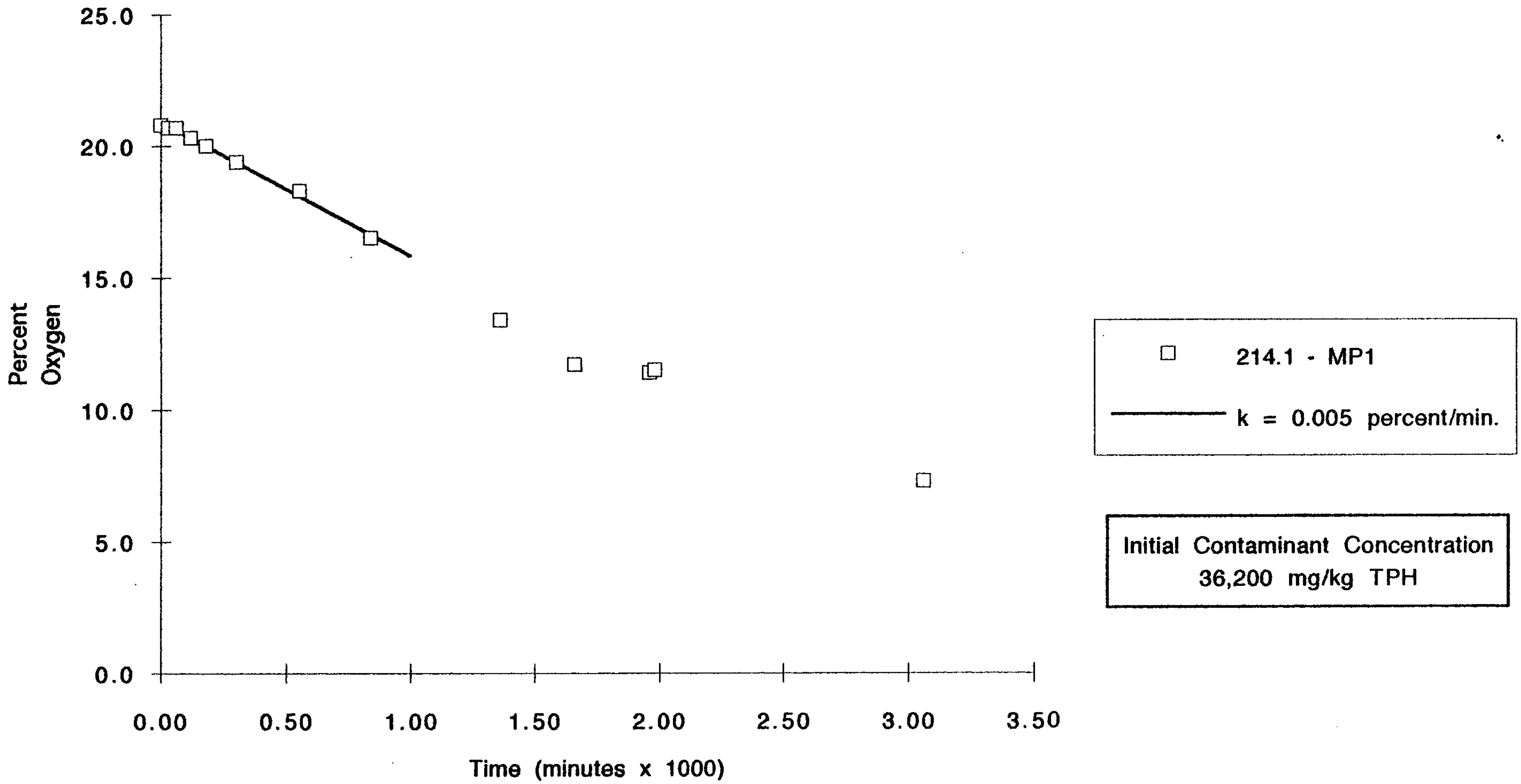
Initial bioventing tests on this site indicate that air extraction is an effective method of increasing oxygen levels in soil gas and potentially increasing aerobic fuel biodegradation. AFCEE has recommended that bioventing continue on this site to determine the long term radius of oxygen influence and the effect of time, available nutrients and changing temperatures on fuel biodegradation rates.

TABLE 2.4
SITE 214.1
INFLUENCE OF AIR EXTRACTION ON VENT WELL
AND MONITORING POINT OXYGEN LEVELS

Monitoring Point	Distance From Vent Well (ft)	Depth (feet bgs)	Initial O2(%)	Final O2(%)
MP1	5	12	10	17.4
SB214A-01	NA a/	5-60	8.7	16.6 b/

a/ NA = Not applicable.
b/ Sample of the vent well exhaust.

Figure 2.3
Respiration Test
Site 214.1 - MP1
Hill AFB, Utah



Resp. Test Chart Site 214.1

8/18/92

TABLE 2.5

APPARENT AND CORRECTED OXYGEN UTILIZATION RATES (0-500 MINUTES)

	Apparent O_2 loss (%/min)	Fractional Helium Loss (%)	Fractional O_2 Diffusion (%)	Estimated O_2 Diffusion (%/min)	Corrected O_2 Utilization (%/min)
MP1	.005	35**	12**	.002**	.003

** Based on helium diffusion from SB204A-02 at Site 204.1.

A7-4-16

A small regenerative blower has been installed on the site (Figure 2.1) to continue a low rate of air extraction. Laboratory analysis of vent well exhaust indicates initial TVH concentrations of 840 ppmv can be expected in the soil gas. To prevent the possible movement of those vapors into nearby buildings or utility corridors, the system will be operated as an extraction system until TVH concentrations are reduced to less than 100 ppmv levels. At this time, the blower piping will be reversed to inject air into the soil and eliminate any additional emission to the atmosphere. In December of 1992, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. The reconfiguration of the system from extraction to injection could be completed at this time. In July of 1993, a final respiration test will be completed and soil and soil gas samples collected from the site to determine the degree of remediation achieved during the first year.

Based on the results of the first year of bioventing, AFCEE will recommend one of two options:

1. Continued operation of the bioventing system for full-scale remediation of the site.
2. If significant difficulties or poor results are encountered within bioventing on this site, AFCEE could recommend the removal of the blower system and proper abandonment of the vent well.

3.0 SITE 228

3.1 Pilot Test Design

The following sections describe the final design and installation of the bioventing system at Site 228. The vent well and vapor monitoring point were installed by another Air Force contractor in March and May 1992, prior to ES involvement. ES installed a blower system in July 1992, in the location specified in the test work plan. Figure 3.1 depicts the actual location of the blower unit at Site 228.

Soils on Site 228 consist of fine- to medium-grained sand with occasional thin clay lenses. Groundwater occurs at 109 feet bgs, and is not impacted by hydrocarbon contamination from the USTs (Montgomery, July 1992c).

3.1.1 Air-Injection Vent Well

The air-injection vent well was installed in May 1992 by another Air Force contractor following procedures described in the protocol document (Hinchee et al., 1992). The location of the vent well is illustrated in Figure 3.1, and construction details for the vent well can be found in Appendix A. The Air Force has designated the vent well as T-228-2-VW-U-92-HF. For purposes of simplicity, the vent well is designated "VW" throughout the remainder of the section. The vent well was installed in a borehole near the northeast corner of Building 228, where hydrocarbon contamination had been detected in a soil sample taken from 27.5 to 28 feet bgs (Figure 3.1). The vent well had been constructed using 4-inch diameter PVC casing with 0.020-inch screen extending from 10 to 40 feet bgs. The annular space between the casing and borehole was filled with 8-12 silica sand to

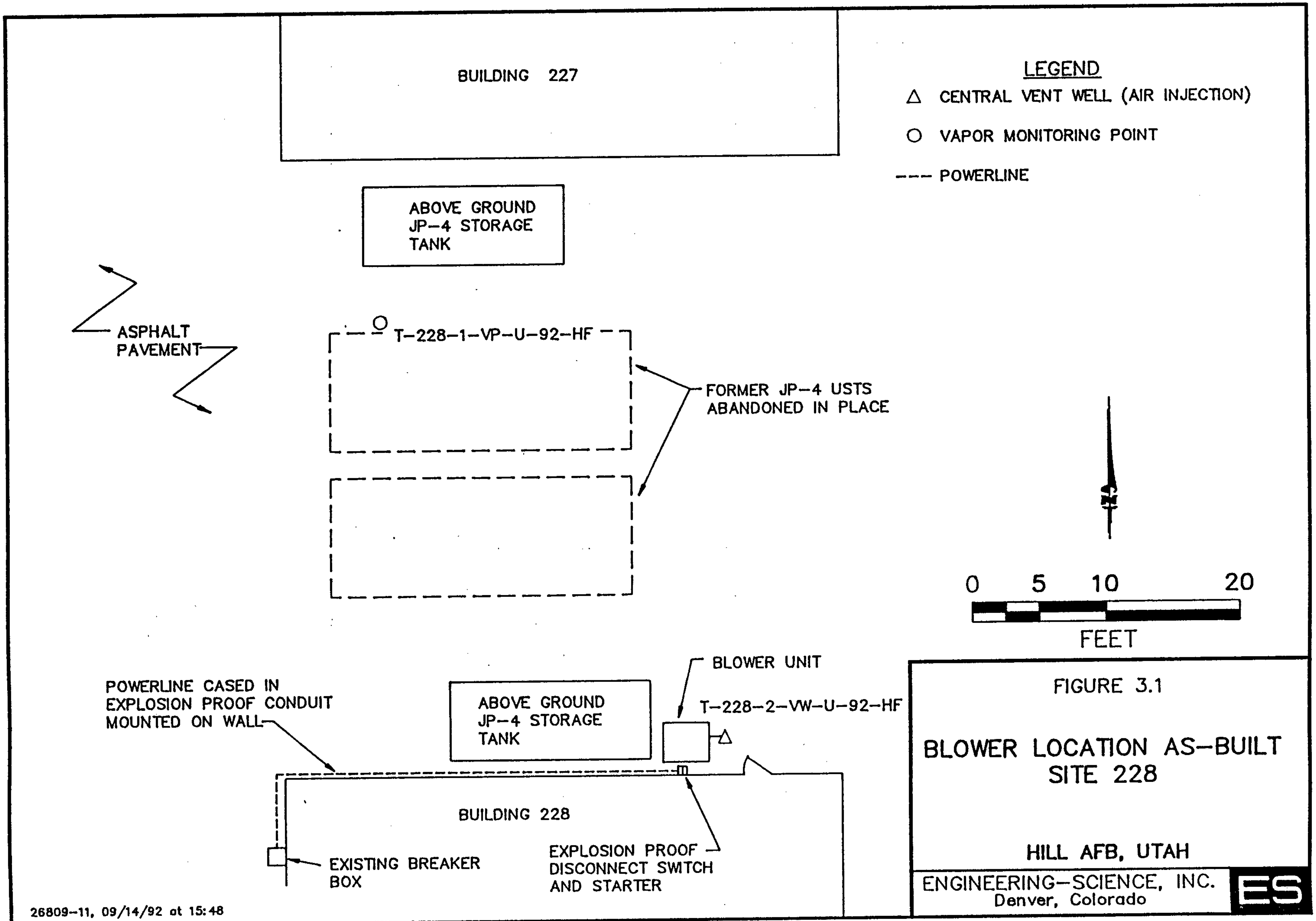


FIGURE 3.1

BLOWER LOCATION AS-BUILT
SITE 228

approximately 2 feet above the well screen. Two feet of bentonite was placed above the sand, followed by a cement grout to the ground surface (Montgomery, July 1992c).

3.1.2 Monitoring Point

One vapor monitoring point, designated by the Air Force as T-228-1-VP-U-92-HF, was installed in March 1992 by another Air Force contractor following procedures described in the protocol document. The monitoring point is referred to as "MP" throughout the remainder of the section. The location of the MP is illustrated in Figure 3.1, and construction details for the MP can be found in Appendix A. The MP was installed in a borehole near the southwest corner of Building 227 (Figure 3.1). The screen consisted of a 1-foot section of PVC well screen 2 inches in diameter, and was installed from 28 to 29 feet bgs, the interval at which hydrocarbon contamination had been detected in a laboratory soil sample. A section of 0.25-inch inside diameter rigid plastic tubing extends from the monitoring point to the ground surface, where a flush-mounted well head cover protects the point.

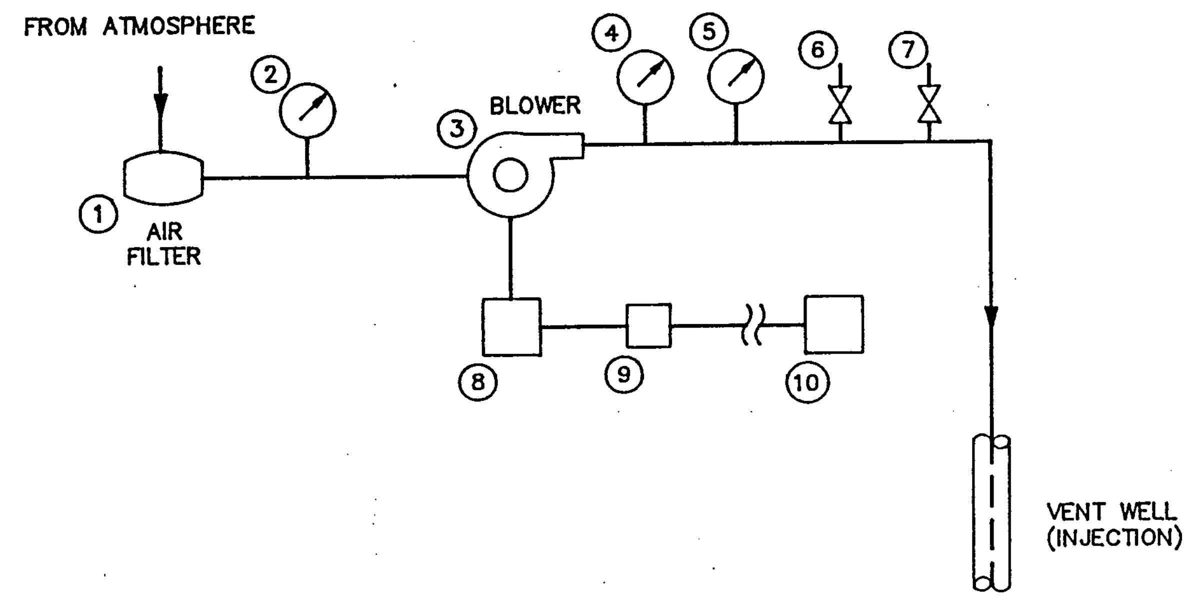
3.1.3 Blower Unit

A 1-horsepower Gast® R4110-2 regenerative blower unit was used at Site 228 for both the initial and extended pilot tests. The blower unit is energized by 110-volt, single phase, 30-amp line power from a breaker box on the west side of Building 228 (Figure 3.1). An explosion-proof starter, disconnect switch, and conduit were installed according to NEC code for Class I, Division I areas. The configuration, instrumentation, and specifications for this system are shown on Figure 3.2. The blower is currently operating at a wellhead pressure of 6 inches H_2O and 66 scfm. A portion of this air flow is being diverted from the system through the bleed valve. The bleed valve is open 1.5 turns to optimize and minimize the flow of air being injected into the soil. By reducing the air injection rate, the subsurface transport of volatile contaminants through the soil gas is minimized and the risk of explosive vapor accumulation in confined spaces is minimized. A copy of the blower operation and maintenance check list provided to the base is found in Appendix B.

3.2 Soil and Soil Gas Sampling Results

Based on the site investigation by James M. Montgomery, Inc. (July 1992c), the vertical extent of contamination appears to be limited to approximately 34 feet bgs. No contamination was detected in T-228-3-BH-U-HF, roughly 40 feet west of the USTs, suggesting that the areal extent of contamination may be limited within a 40-foot radius from the USTs (Montgomery, July 1992c). Soil analytical results are summarized in Table 3.1.

Laboratory soil gas samples were collected from the monitoring point on July 6, 1992, and the vent well on July 7, 1992. The MP was purged for 1 minute and the vent well was purged for 20 minutes prior to sample collection using a 1-scfm vacuum pump. Soil gas samples were shipped via Federal Express® to Air Toxics, Inc. in Rancho Cordova, California, for TPH (referenced to JP-4 jet fuel) and



LEGEND

1. INLET AIR FILTER - SOLBERG F–18P–150
2. VACUUM GAUGE (In H_2O)
3. BLOWER – GAST R4110–2
4. PRESSURE GAUGE (In H_2O)
5. TEMPERATURE GAUGE (°F)
6. AUTOMATIC PRESSURE RELIEF VALVE (SET AT 42 In H_2O)
7. MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2" GATE
8. EXPLOSION PROOF STARTER – FURNAS 14CSE33HA
9. EXPLOSION PROOF DISCONNECT SWITCH
10. BREAKER BOX

FIGURE 3.2

AS–BUILT BLOWER SYSTEM FOR AIR INJECTION SITE 228

HILL AFB, UTAH

ENGINEERING–SCIENCE, INC.
Denver, Colorado

ES

26809–09, 09/14/92 at 15:59

TABLE 3.1
SITE 228
SOIL AND SOIL GAS ANALYTICAL RESULTS

Analyte (Units) a/	Sample Location (feet bgs)		
Soil Hydrocarbons b/	MP (28-28.5) c/		VW (27.5-28) d/
TPH (mg/kg)	6500		5000
Benzene (mg/kg)	0.08		1.2
Toluene (mg/kg)	6.3		12
Ethylbenzene (mg/kg)	8.1		6.1
Xylenes (mg/kg)	260		220
Soil Gas Hydrocarbons	MP (28-29)	MP (28-29) (lab duplicate)	VW (10-40)
TPH (ppmv) e/	2500	2900	42
Benzene (ppmv)	1.6	1.5	0.06
Toluene (ppmv)	4.4	4.4	0.00
Ethylbenzene (ppmv)	1.7	1.7	0.00
Xylenes (ppmv)	9.2	9.7	0.01
Soil Physical Parameters b/	VW (20-20.5)	VW (41-41.5)	
Moisture (% wt.)	6.9	16.5	
Gravel (%)	0	0	
Sand (%)	94	68	
Silt (%)	2	25	
Clay (%)	4	7	

a/ mg/kg=milligrams per kilogram; ppmv=parts per million, volume per volume.
b/ Montgomery, July 1992c.
c/ MP = Monitoring Point T-228-1-VW-92-HF.
d/ VW = Vent Well T-228-2-BH-92-HF.
e/ TPH referenced to Jet Fuel (molecular weight=156).

BTEX analyses by Method TO-3. The results of these analyses are provided in Table 3.1. A laboratory duplicate sample from the MP was analyzed. Results matched the primary sample very closely, indicating highly precise analyses. The soil gas sample from the VW contained TPH at a concentration of only 42 ppmv. The VW is screened between 10 and 40 feet bgs, and the soil gas TPH concentration represents an average concentration over this interval. The low TPH concentration from the vent well suggests that only a thin zone of soil in the screened interval is contaminated.

3.3 Exceptions to Test Protocol

Procedures described in the protocol document were used to complete treatability tests at Site 228, with the following exceptions. The first *in situ* respiration test was performed before the air permeability test, which is in reverse order to the protocol procedure. No negative impacts were observed; sufficient time was allowed for the soil gas to return to initial conditions before the air permeability test was started.

Air and helium injection prior to the first respiration test was performed using an alternative method to that specified in the protocol document. Air and helium were injected by metering two premixed 230 cubic foot cylinders containing 1.5 percent helium and 98.5 percent air into the monitoring point. It was difficult to maintain a constant gas bleed rate using the SR250D regulators. The second respiration test was performed by oxygenating contaminated soil using the blower unit rather than the small 1-scfm vacuum pumps.

In many cases, it was not possible to purge the vent well and the monitoring point according to protocol procedures. During both respiration tests, airplane fuel tanks were being purged onsite and the 1-scfm purge pumps could not be used due to the explosion hazard. Therefore, purging was performed by using the small internal pump of the O_2/CO_2 analyzer. Respiration results were only obtained for the monitoring point; the casing volume of the vent well is much too large to purge using the small pump within the O_2/CO_2 meter. Inconsistencies observed during respiration testing at Site 228 may be partly attributed to this undesirable purging method. Future respiration testing will attempt to overcome this purging limitation.

3.4 Test Results

3.4.1 Initial Soil Gas Chemistry

Prior to initiating air injection at Site 228, soil gas from the vent well and the monitoring point was sampled to determine initial oxygen, carbon dioxide, and TVH concentrations. The vent well was purged for 20 minutes and the monitoring point was purged for 1 minute using a 1-scfm purge pump prior to sample collection. Gas samples were analyzed using portable gas analyzers described in the protocol document. Table 3.2 summarizes the initial soil gas chemistry at Site 228. Oxygen was depleted but not absent at both locations, indicating the presence of biological activity, and also suggesting that oxygen may be diffusing into contaminated regions from nearby clean soils. The field TVH detection at the vent well was only 82 ppmv, indicating that only a thin interval of soil is contaminated in the screened

TABLE 3.2
SITE 228
INITIAL SOIL GAS CHEMISTRY

Monitoring Point	Depth (ft bgs)	O2 (%)	CO2 (%)	TVH (ppmv)
MP	28-29	4.8	12	1250
VW	10-40	6.3	10.7	82

interval of the vent well. Both the vent well and the monitoring point are on the periphery of the UST locations. Anaerobic soil zones may exist underneath the abandoned USTs, where hydrocarbon contamination may be present at higher concentrations. However, there are insufficient soil gas monitoring points on the site to pinpoint the anaerobic soil volume.

3.4.2 Soil Gas Permeability

A soil gas permeability test was conducted according to protocol procedures. Air was injected into the VW at a rate of approximately 78 scfm and an average pressure of approximately 8 inches H_2O. The pressure response at the monitoring point is listed in Table 3.3. Due to the rapid response and relatively short time to steady-state conditions, the steady-state method of determining soil gas permeability was selected. As discussed in the protocol, the dynamic method of determining soil gas permeability that is coded in the Hyperventilate® model is not appropriate for soils that reach steady state in less than 10 minutes. Using the steady-state method, a soil gas permeability value of 30 to 40 darcies was estimated.

3.4.3 Oxygen Influence

The depth and radius of oxygen increase in the subsurface resulting from air injection in the central vent well is the primary design parameter for bioventing systems. Optimization of full-scale and multiple vent well systems requires pilot testing to determine the volume of soil which can be oxygenated at a given flow rate and vent well screen configuration.

Table 3.4 describes the change in soil gas oxygen levels that occurred during 27.5 hours of air injection into the Site 228 vent well at an average flow rate of 78 scfm. This relatively brief air injection period produced a radius of oxygen influence of at least 39 feet in site soils. It is our opinion that the radius of oxygen influence for a long-term bioventing system on this site will exceed 39 feet at all depths, and that the entire contaminated region is being supplied with oxygen. Future monitoring at this site will better define the treatment radius.

3.4.4 In Situ Respiration Rates

The results of *in situ* respiration testing at Site 228 are presented in Figures 3.3 through 3.5. Two respiration tests were performed at Site 228. The first respiration test was performed on 7-9 July, 1992, and the second test was performed on 25-27 July 1992. Anomalous results were obtained during both respiration tests. Measured oxygen and helium concentrations tended to fluctuate, rather than decrease in a linear fashion. The inconsistencies observed during respiration testing at Site 228 may be partly attributed to the undesirable purging method that was used. During respiration testing, it was not possible to purge the vent well and the monitoring point according to protocol procedures. Hill AFB personnel would not allow the use of the l-scfm purge pumps due to the possible explosion hazard. Therefore, purging was performed using the small internal pump of the O_2/CO_2 analyzer. It is not likely that the small pump in the O_2/CO_2 meter provides enough air flow for consistent purging.

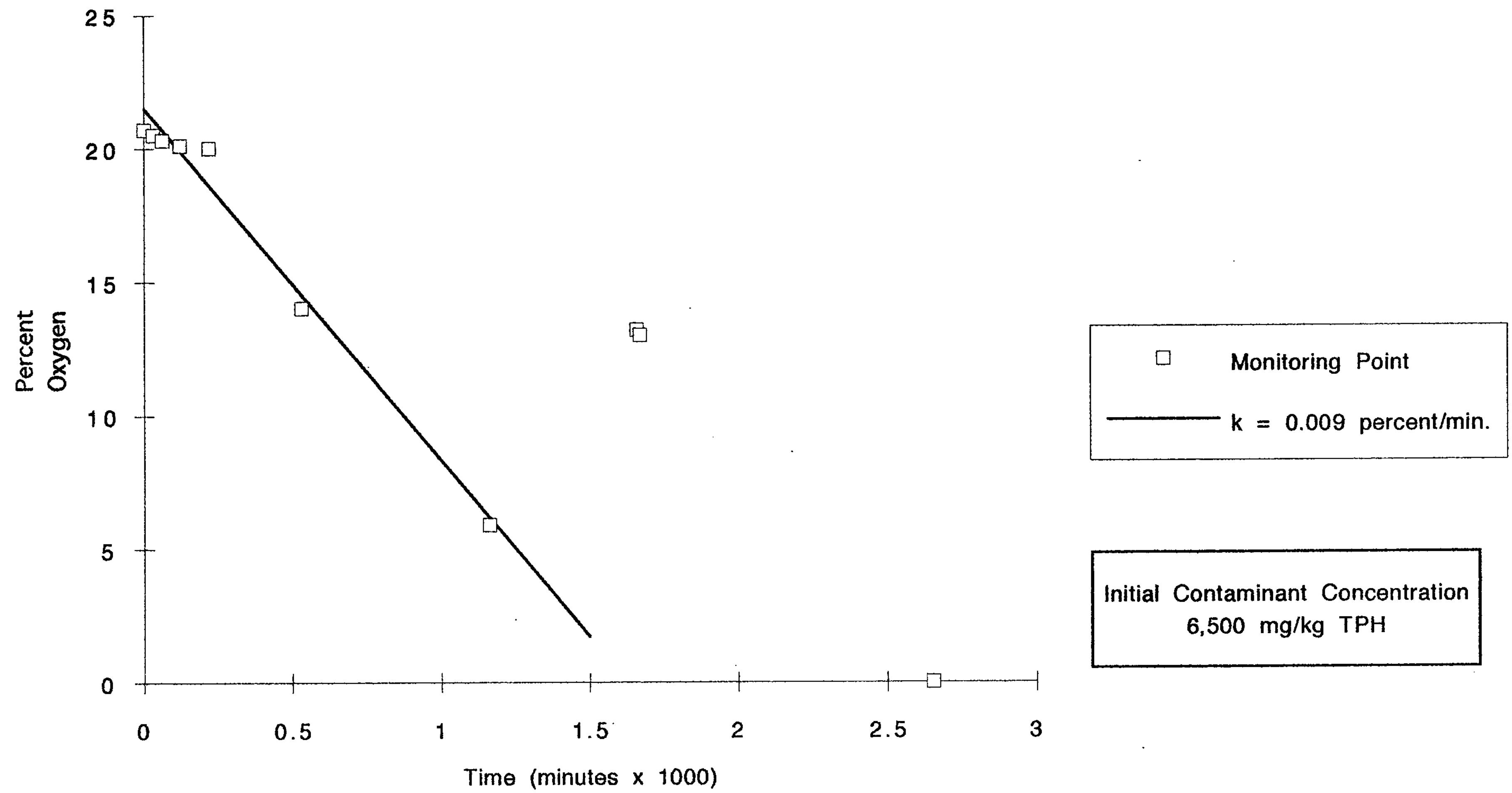
TABLE 3.3
SITE 228
PRESSURE RESPONSE
AIR PERMEABILITY TEST

Elapsed Time (min)	Pressure Response at MP,28-29 ft bgs (inches of water)
0	0.2
2	0.5
3	0.6
4	0.7
6	0.75
8	0.75
10	0.8
13	0.8
19	0.85
23	0.9
38	0.9
48	0.9
68	0.9
88	0.85
103	0.85
118	0.85
153	0.65
178	0.6
203	0.6
238	0.55
253	0.45
283	0.7
303	0.8
1078	0.45
1643	0.65

TABLE 3.4
SITE 228
INFLUENCE OF AIR INJECTION AT VENT WELL
ON MONITORING POINT OXYGEN LEVELS

Monitoring Point	Distance From Vent Well (ft)	Depth (feet bgs)	Initial O2(%)	Final O2(%)
MP	38.83	28–29	8.4	19.5

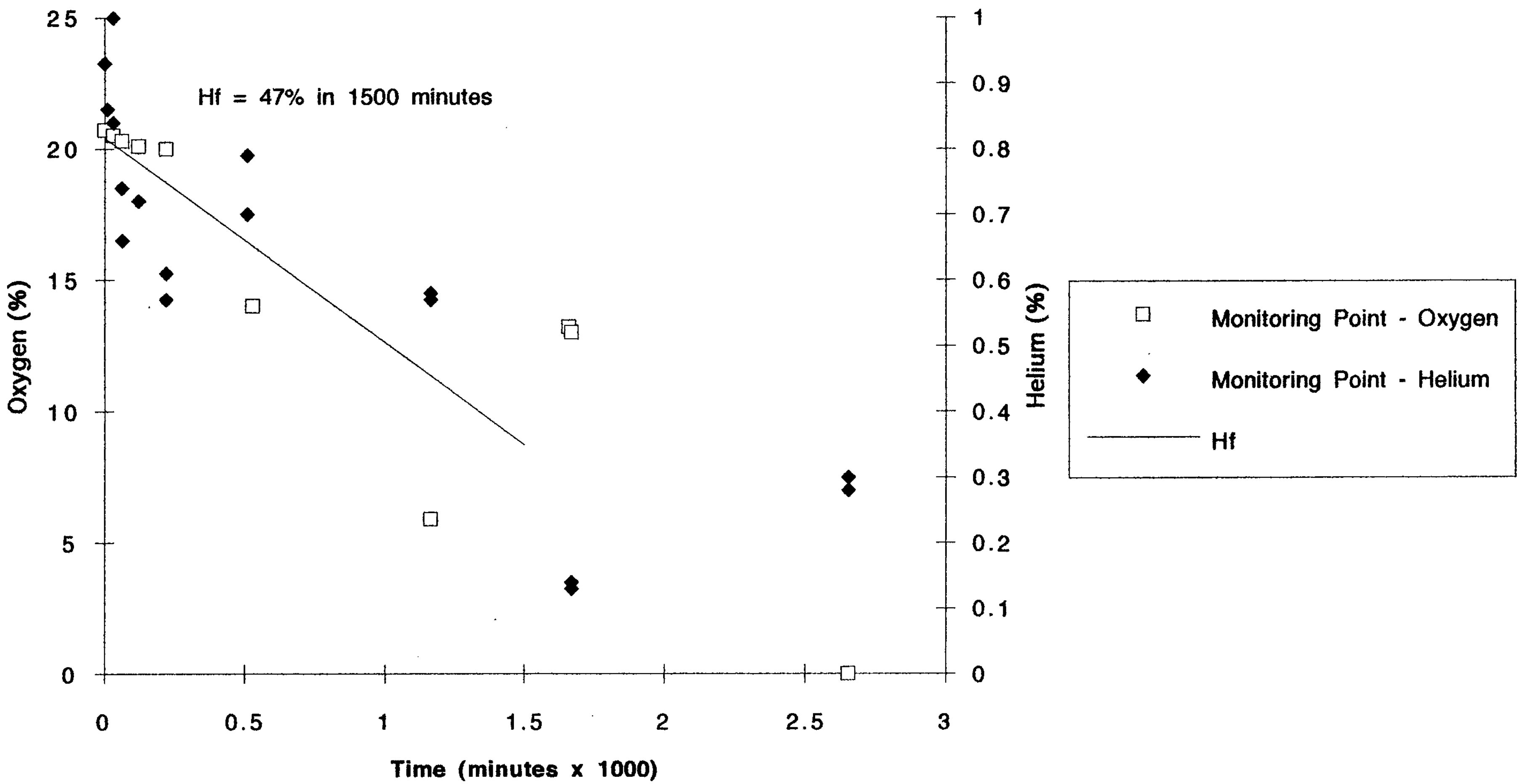
Figure 3.3
Respiration Test on 7-9 July 1992
Site 228 - Monitoring Point
Hill AFB, Utah



R. T. Chart Site 228 V Probe

9/11/92

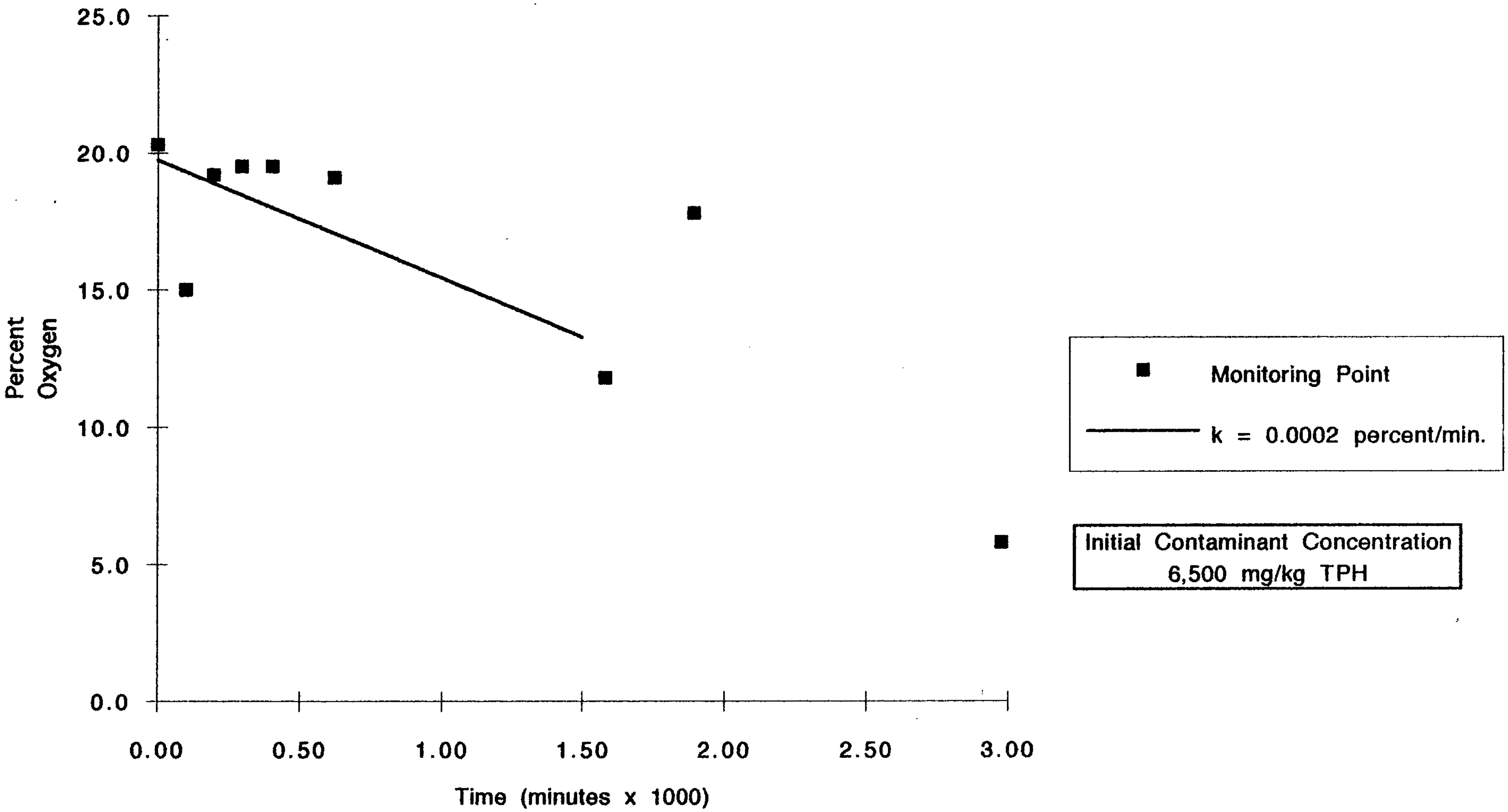
Figure 3.4
Respiration Test on 7-9 July 1992
Oxygen/Helium Concentrations
Site 228 - Monitoring Point
Hill AFB, Utah



O2/Helium 228 - V Probe

9/11/92

Figure 3.5
Respiration Test on 25-27 July 1992
Site 228 - Monitoring Point
Hill AFB, Utah



Resp. Test Chart Site 228 MP

8/18/92

Oxygen consumption rates, diffusion rates, and fuel degradation rates were estimated using data from the first 1,500 minutes of the *in situ* respiration test performed on 7-9 July 1992 (Figures 3.3 and 3.4). In general, data obtained during this test was more consistent than the data obtained during testing on 25-27 July 1992 (Figure 3.5). The greatest inconsistency during the test on 7-9 July 1992 was the data obtained 1,600 minutes after the start of the respiration test. Oxygen levels had been decreasing linearly (Figure 3.3), and had been measured at 5.9 percent at 1,100 minutes. At 1,600 minutes the oxygen level had increased to 13.2 percent, and the result was reproducible. Also, helium was detected at only 0.13 percent at 1,600 minutes, the lowest concentration obtained during the test (Figure 3.4). The combination of the high oxygen level and low helium concentration suggests that leakage may have occurred during sample collection at 1,600 minutes, allowing atmospheric oxygen into the samples and allowing the release of helium from the sample. Thus, data collected at 1,600 minutes was not used in estimating oxygen consumption rates.

During the respiration test performed on 7-9 July 1992, helium diffusion at the monitoring point resulted in a fractional loss of approximately 47 percent of the initial helium concentration in the first 1,500 minutes of the test (Figure 3.4). Due to its greater molecular weight, oxygen will diffuse approximately three times slower than helium. This means that at the monitoring point, approximately 16 percent of the initial oxygen may have been lost due to diffusion during the initial 1,500 minutes. Table 3.5 provides a summary of the observed and corrected oxygen utilization rates for Site 228.

Based on the oxygen utilization rates observed at the monitoring point during the initial 1500 minutes, an estimated 4.18 milligrams of fuel per kilogram of soil can be degraded each day on this site. This estimate is based on an average air-filled porosity of .095 liters per kilogram of soil and a conservative ratio of 3.5 milligrams of oxygen consumed for every 1 milligram of fuel degraded.

3.5 Recommendations

Initial bioventing tests on this site indicate that oxygen has been depleted in contaminated soils and that air injection is an effective method of increasing aerobic fuel biodegradation. AFCEE has recommended that air injection continue on this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients and changing temperatures on fuel biodegradation rates.

A small regenerative blower has been installed on the site (Figure 3.1) to continue a low rate of air injection. In December of 1992, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. To improve respiration test results, the well purging method outlined in the protocol document will be used. Arrangements will be made in advance to conduct the test when airplane fuel tanks are not being purged and there is no explosion hazard. In July of 1993, a final respiration test will be completed and soil gas samples collected from the site to determine the degree of remediation achieved during the first year.

TABLE 3.5

APPARENT AND CORRECTED OXYGEN UTILIZATION RATES (0-1500 MINUTES)

	Apparent O_2 loss (%/min)	Fractional Helium Loss (%)	Fractional O_2 Diffusion (%)	Estimated O_2 Diffusion (%/min)	Corrected O_2 Utilization (%/min)
MP **	.009	47	16	.001	.008

** Based on data from 7-9 July 1992.

A7-4-17

Based on the results of the first year of bioventing, AFCEE will recommend one of three options:

1. Continued operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the base in obtaining regulatory approval for upgrade and continued operation.
2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that clean up criteria have been achieved.
3. If significant difficulties or poor results are encountered within bioventing on this site, AFCEE could recommend the removal of the blower system and proper abandonment of the vent well.

4.0 SITE 924

4.1 Pilot Test Design

The following sections describe the final design and installation of the bioventing system on Site 924. A horizontal venting pipe and six vapor monitoring points were installed in the former UST excavation by another Air Force contractor in June 1992, prior to ES involvement. ES installed a single blower unit at Site 924 in July 1992 at the location indicated in the test work plan. Figure 4.1 depicts the actual locations of the blower unit, venting pipe, and vapor monitoring points at Site 924.

Soils at this site consist of medium-grained, coarse-grained, and well-sorted sands to depths of at least 35 feet bgs. Groundwater occurs at approximately 60 feet bgs at Site 924 (Montgomery, December 1991b).

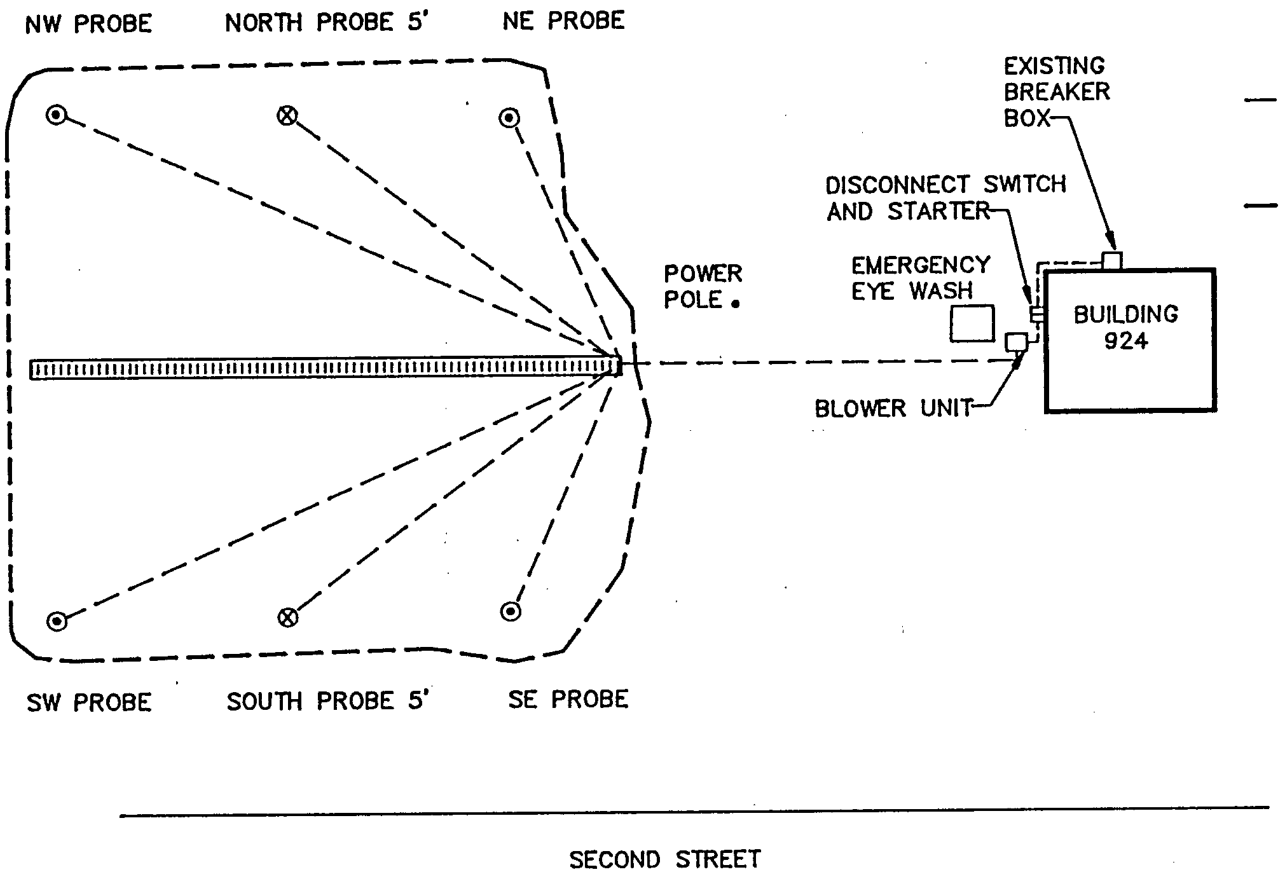
4.1.1 Air-Injection Venting Pipe

The horizontal air-injection venting pipe was installed on the floor of the former UST excavation. The perforated section consisted of 4-inch drain tile with a geofabric wrap. The perforated section is approximately 100 feet long, and extends from west to east along the center of the former excavation. The west end of the perforated pipe was capped, while the east end was connected to non-perforated, 4-inch diameter ABS pipe that comes to the surface west of Building 924 (Figure 4.1). The depth of the horizontal perforated section is approximately 12 feet bgs.

4.1.2 Monitoring Points

Six monitoring points were installed in the former UST excavation by another Air Force subcontractor prior to ES involvement. Each monitoring point was constructed with a 1-foot section of 1-inch diameter PVC well screen connected to 0.38-inch outside diameter rigid plastic tubing. Each section of tubing extends underground from its respective monitoring point to the west side of Building 924, where they come to the surface (Figure 4.1). At the surface, the tubing runs into the blower shed. Each section of tubing is labeled with metallic tape as described in the protocol document.

The four monitoring points at the corners of the excavation (NW Probe, NE Probe, SW Probe, and SE Probe) were installed at 12 feet bgs, and the two



LEGEND

- PERFORATED 4-INCH DRAIN PIPE (AIR INJECTION GALLERY)
- ⊙ VAPOR MONITORING POINT (12 FEET DEEP)
- ⊗ VAPOR MONITORING POINT (5 FEET DEEP)
- – – – 3/8-INCH PLASTIC TUBING (VAPOR MONITORING POINTS) OR 4-INCH ABS PIPE (AIR INJECTION GALLERY)
- – – – APPROXIMATE LIMITS OF UST EXCAVATION

FIGURE 4.1

BLOWER LOCATION AS-BUILT
SITE 924

HILL AFB, UTAH

ENGINEERING-SCIENCE, INC.
Denver, Colorado

26809-04, 09/14/92 at 16:04

remaining probes (North Probe and South Probe) were installed at 5 feet bgs. Each monitoring point is approximately 15 to 25 feet away from the horizontal vent pipe.

4.1.3 Blower Unit

A 2.5-horsepower Gast® 5125-2 regenerative blower unit was installed at Site 924, and was used for both the initial air permeability test and extended pilot test. The blower unit is powered by 230-volt, single-phase line power from an existing breaker box on the north side of Building 924. The configuration, instrumentation, and specifications for this system are shown on Figure 4.2. The bleed valve is currently open 1.5 turns to optimize the flow rate of air being injected in to the soil. The objective is to oxygenate the entire contaminated area with the lowest possible air injection rate; this minimizes the vapor transport of contaminants through the soil. A copy of the blower operation and maintenance check list provided to the base is found in Appendix B.

4.2 Soil and Soil Gas Sampling Results

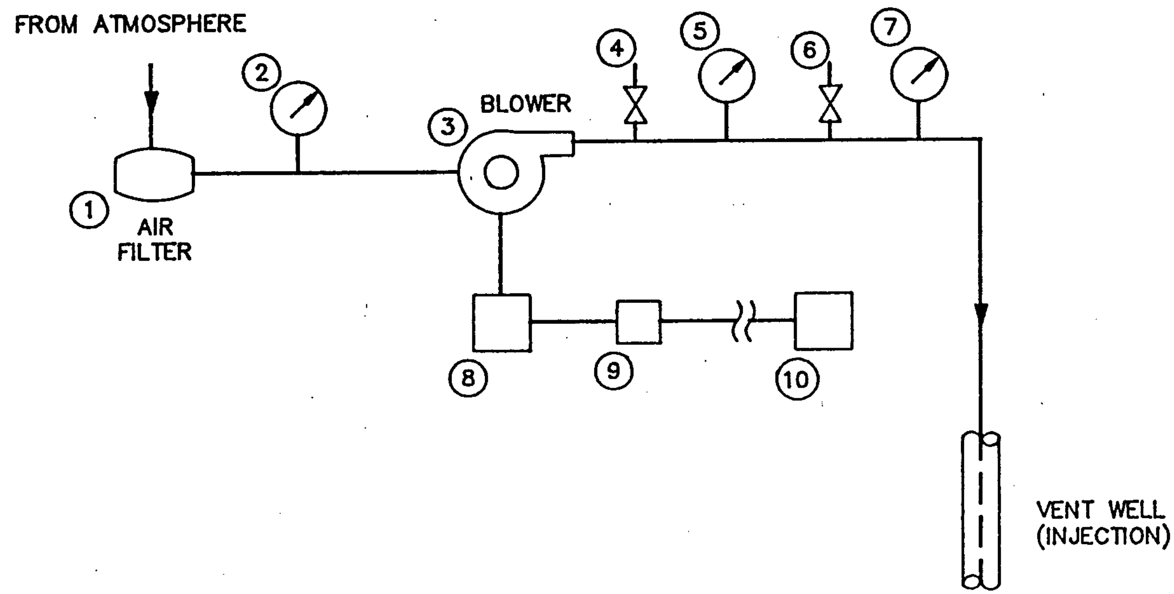
To date, no soil analytical data is available, and the extent of hydrocarbon contamination at Site 924 is not yet fully defined. Laboratory soil gas samples were collected from the vent well and two of the monitoring points. The vent well was purged for 20 minutes prior to sampling, and each monitoring point was purged for 1 minute. Soil gas samples were shipped via Federal Express® to Air Toxics, Inc. in Rancho Cordova, California for TPH and BTEX analyses by Method TO-3. TPH analyses were referenced to gasoline. The results of these analyses are provided in Table 4.1. A field duplicate sample was collected from the SE Probe to ascertain the precision of laboratory analytical procedures and field sampling procedures. The duplicate sample was submitted to the laboratory under the fictitious name "WP", and these results are included in Table 4.1. A comparison of the results from the primary sample and the duplicate show that field sample collection and laboratory analyses are being performed in a precise manner.

4.3 Exceptions to Test Protocol

Procedures contained in the protocol document were used to complete treatability tests at Site 924. Due to the delayed shipment of the blower unit, the sequence of *in situ* respiration testing and soil gas permeability testing had to be reversed. Although the respiration test was performed first, enough time was provided for the soil gas to return to initial conditions prior to the start of the air permeability test.

Helium injection was performed using an alternative to the protocol method as described in Section 1.3. The helium/air mixture was bled into the SE Probe over a ten hour period at an average flow rate of 0.4 cfm.

At Site 924, the monitoring points and the vent well were constructed in a manner that differed from protocol instructions. The vent well was composed of a 100-foot section of perforated drain tile, set horizontally on the floor of the former UST excavation while it was still open. Four monitoring points were placed in the corners of the excavation, and two others were placed on the sides. The excavation was backfilled with fuel-contaminated soil that had been removed during initial



LEGEND

1. INLET AIR FILTER – SOLBERG F–18P–150
2. VACUUM GAUGE (in H_2O)
3. BLOWER – GAST R5125Q–50
4. AUTOMATIC PRESSURE RELIEF VALVE (SET AT 42 in H_2O)
5. PRESSURE GAUGE (in H_2O)
6. MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2" GATE
7. TEMPERATURE GAUGE (°F)
8. STARTER – FURNAS 14CSE33DA NEMA 3
9. DISCONNECT SWITCH
10. BREAKER BOX

FIGURE 4.2

AS–BUILT BLOWER SYSTEM FOR AIR INJECTION SITE 924

HILL AFB, UTAH

ENGINEERING–SCIENCE, INC.
Denver, Colorado

ES

26809–10, 09/14/92 at 11:29

TABLE 4.1
SITE 924
SOIL GAS ANALYTICAL RESULTS

Analyte (Units) a/	Sample Location (feet bgs)			
Soil Gas Hydrocarbons	Vent Well	SE Probe	SE Probe (dup)	South Probe
TPH (ppmv) c/	13	4700	4900	1800
Benzene (ppmv)	0.016	60	62	15
Toluene (ppmv)	0.12	140	150	30
Ethylbenzene (ppmv)	0.013	6.5	6.8	1
Xylenes (ppmv)	0.16	62	65	8.6

a/ mg/kg=milligrams per kilogram; ppmv=parts per million, volume per volume.
b/ Field duplicate labeled as WP on chain of custody form.
c/ TPH referenced to Gasoline (molecular weight=100).

excavation activity. Sections 4.1.1 and 4.1.2 describe the construction of the venting pipe and the monitoring points. The vent well and monitoring points had been installed by another Air Force subcontractor prior to ES involvement.

4.4 Test Results

4.4.1 Initial Soil Gas Chemistry

On 18 June 1992, soil gas from all monitoring points and the vent well was sampled to determine initial oxygen, carbon dioxide, and TVH concentrations. The vent well was purged for 20 minutes and the monitoring points were purged for 1 minute using a 1-scfm purge pump prior to sample collection. The samples were analyzed in the field using portable gas analyzers as described in the protocol. Table 4.2 summarizes the initial soil gas chemistry at Site 924. The S Probe and the SE Probe were under anaerobic conditions and contained TVH at concentrations in excess of 10,000 ppmv, indicating that biological fuel degradation was occurring in these highly contaminated areas on the south side of the former UST excavation. Oxygen levels on the north side of the excavation ranged from 9.5 percent to 14.2 percent. This may indicate that fuel biodegradation is also occurring at these locations, or that oxygen may be lost through natural diffusion to heavily contaminated soils on the south side of the excavation.

4.4.2 Soil Gas Permeability

A soil gas permeability test was conducted according to protocol procedures. Air was injected into the vent well at a rate of approximately 77 scfm and an average well head pressure of approximately 10 inches H_2O. The pressure response at each monitoring point is recorded in Table 4.3. Due to the rapid response and relatively short time to steady state conditions, the steady state method of determining soil gas permeability was selected. As discussed in the protocol, the dynamic method of determining soil gas permeability that is coded in the Hyperventilate® model is not appropriate for soils which reach steady state in less than 10 minutes. Using the steady state method, a soil gas permeability value of 15-25 darcies was estimated for the backfilled soil. It was not possible to calculate a radius of pressure influence or a site-specific darcy value, because the distances from the monitoring points to the vent well are not known.

4.4.3 Oxygen Influence

The depth and radius of oxygen increase in the subsurface resulting from air injection in the central vent well is the primary design parameter for bioventing systems. Optimization of full-scale and multiple vent well systems requires pilot testing to determine the volume of soil which can be oxygenated at a given flow rate and vent well screen configuration.

Table 4.4 describes the change in soil gas oxygen levels that occurred during a 6.5 hour period of air injection into the Site 924 vent well. Significant oxygen increases occurred at all locations, indicating that the entire volume of backfilled soil is being provided with oxygen. It is also likely that a significant volume of adjacent undisturbed soil is also being oxygenated.

TABLE 4.2
SITE 924
INITIAL SOIL GAS CHEMISTRY

Monitoring Point	Depth (ft bgs)	O2 (%)	CO2 (%)	TVH (ppmv)
Vent Well	12	1.6	13.8	88
SE	12	0	19.5	>10000
S	5	0	20	>10000
SW	12	4	10.6	110
NE	12	14.2	5.4	190
N	5	12.5	7.3	205
NW	12	9.5	6.8	90

TABLE 4.3
SITE 924
PRESSURE RESPONSE AT MONITORING POINTS
AIR PERMEABILITY TEST

Monitoring Point (ft bgs)	SE 12	SW 12	S 5	NW 12	N 5	NE 12
Elapsed Time (minutes)	Pressure Response, inches of water.					
1	0.65	1.8	NS	0.5	NS	NS
2	1	NS	1.2	NS	1.25	NS
3	NS	NS	NS	NS	1.35	0.9
4	1.15	NS	NS	0.9	NS	NS
5	NS	2.2	1.4	NS	1.45	NS
6	1.2	NS	NS	NS	NS	1.2
7	NS	NS	NS	1.1	1.45	NS
8	1.25	2.2	1.7	NS	NS	NS
9	NS	NS	NS	NS	1.45	0.9
10	NS	NS	NS	1	NS	NS
11	1.3	2.2	1.7	NS	1.45	NS
14	1.25	NS	NS	1.1	NS	0.9
15	NS	2	1.5	NS	1.5	NS
20	1.35	2.3	1.5	1.1	1.5	0.9
24	1.35	2.3	1.5	1.2	1.5	1
30	1.35	2.35	1.5	1.2	1.5	NS
38	1.35	NS	NS	NS	1.45	NS
53	NS	2.3	1.45	1.1	NS	0.87
58	1.35	2.2	1.4	1.1	1.5	0.9
66	NS	2.35	1.4	1.2	NS	1
72	1.35	2.3	1.5	1.2	1.5	1
91	1.35	NS	NS	NS	1.5	NS
118	1.35	2.35	1.5	1.2	1.5	1
180	1.35	2.45	1.55	1.27	1.45	1.1
212	1.4	2.45	1.5	1.21	1.5	1.1
235	1.5	2.45	1.5	1.2	1.55	1.1
365	1.2	2.2	1.4	0.97	1.3	1
3103	0.75	1.95	1.3	1	1.2	0.95

NS=Not sampled.

TABLE 4.4
SITE 924
INFLUENCE OF AIR INJECTION AT VENT WELL
ON MONITORING POINT OXYGEN LEVELS

Monitoring Point	Distance From Vent Well (ft)	Depth (feet bgs)	Initial O2(%)	Final O2(%)
NE	Approximately 15 to 25	12	13	20.6
N	Approximately 15 to 25	5	11.7	20.6
NW	Approximately 15 to 25	12	9.4	20.6
SE	Approximately 15 to 25	12	0	19.1
S	Approximately 15 to 25	5	0	18.3
SW	Approximately 15 to 25	12	4.2	20.7

4.4.4 In Situ Respiration Rates

The results of *in situ* respiration testing at Site 924 are presented in Figures 4.3 through 4.7. Oxygen loss from the SW Probe occurred at a steady rate of 0.001 percent per minute over the first 1000 minutes of the test (Figure 4.6). In contrast, oxygen utilization rates at the SE Probe, the South Probe, and the Vent Well ranged from 0.009 to 0.014 percent per minute over the first 1000 minutes; approximately one order of magnitude greater than the oxygen uptake rate at the SW Probe. Hydrocarbon concentrations in soil gas from the SE Probe and the South Probe were greater than 10,000 ppm in June 18, 1992, and initial oxygen levels were entirely depleted. Oxygen in the vent well was present at 1.6 percent, while the sample from the SW probe contained 4.0 percent oxygen. Due to the low hydrocarbon concentrations in the SW probe soil gas, it is likely that the oxygen loss at the SW Probe is due primarily to diffusion.

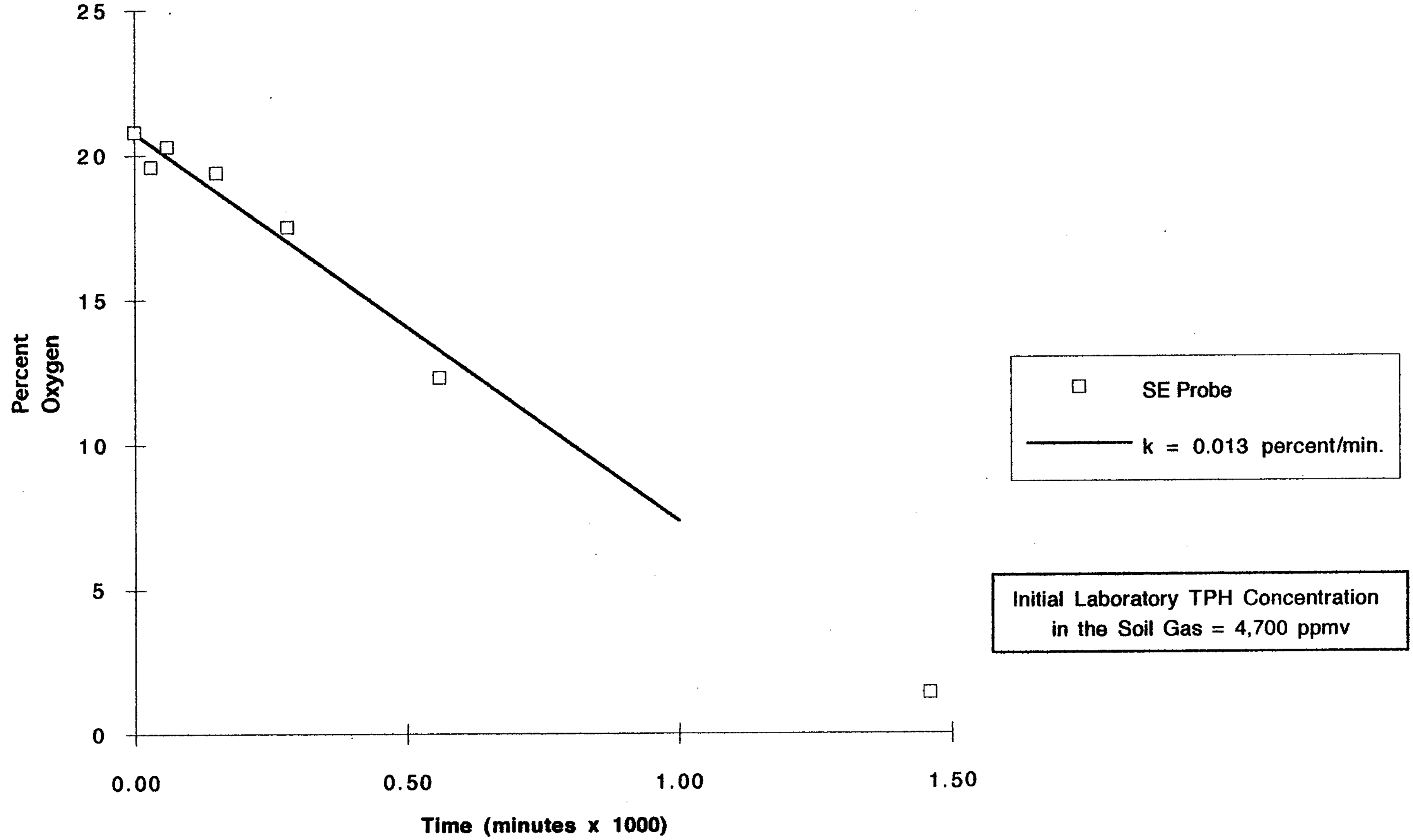
During the initial 500 minutes, helium diffusion at the SE Probe resulted in a fractional loss of approximately 66% of the initial helium concentration (Figure 4.7). Due to the greater molecular weight of oxygen, helium will diffuse approximately three times faster than oxygen. Thus, at the SE Probe, approximately 22 percent of the initial oxygen may have been lost due to diffusion during the initial 500 minutes. Table 4.5 provides a summary of the observed and corrected oxygen utilization rates for Site 924. As the vent well and all six vapor probes were completed in the same soil backfill, oxygen diffusion rates at all probes were assumed to be similar to the rate estimated for the SE Probe.

Based on the average of the diffusion-corrected oxygen utilization rates observed at the vent well, SE Probe and South Probe during the initial 500 minutes, an estimated 7.5 milligrams of fuel per kilogram of soil can be degraded each day on this site. This estimate is based on an average air-filled porosity of .15 liters per kilogram of soil, and a conservative ratio of 3.5 milligrams of oxygen consumed for every 1 milligram of fuel degraded.

At the vent well and the south probe, an apparent decrease in oxygen utilization rates was observed over time (Figures 4.4 and 4.5). This apparent decrease has been observed by ES at other fuel spill sites where contamination levels are variable. Table 4.4 provides initial oxygen levels at the vent well and monitoring points, and clearly illustrates this variability.

The protocol model for helium and oxygen diffusion assumes that each monitoring point is surrounded by contaminated soil with zero oxygen and that the gradient of oxygen diffusion is always outward from the monitoring point. It is apparent that at Site 924, clean, oxygenated soil is in close proximity to zones of contaminated, zero-oxygen soil. In this situation, we believe that the oxygen diffusion gradient actually reverses over time. As oxygen is rapidly consumed by fuel-degrading bacteria, the inward diffusion of oxygen begins from clean soils. The effect of this inward diffusion is an apparent reduction in oxygen utilization rates over time. Because fuel biodegradation generally consumes oxygen at a rate that exceeds diffusion, soil gas eventually returns to zero in contaminated soil.

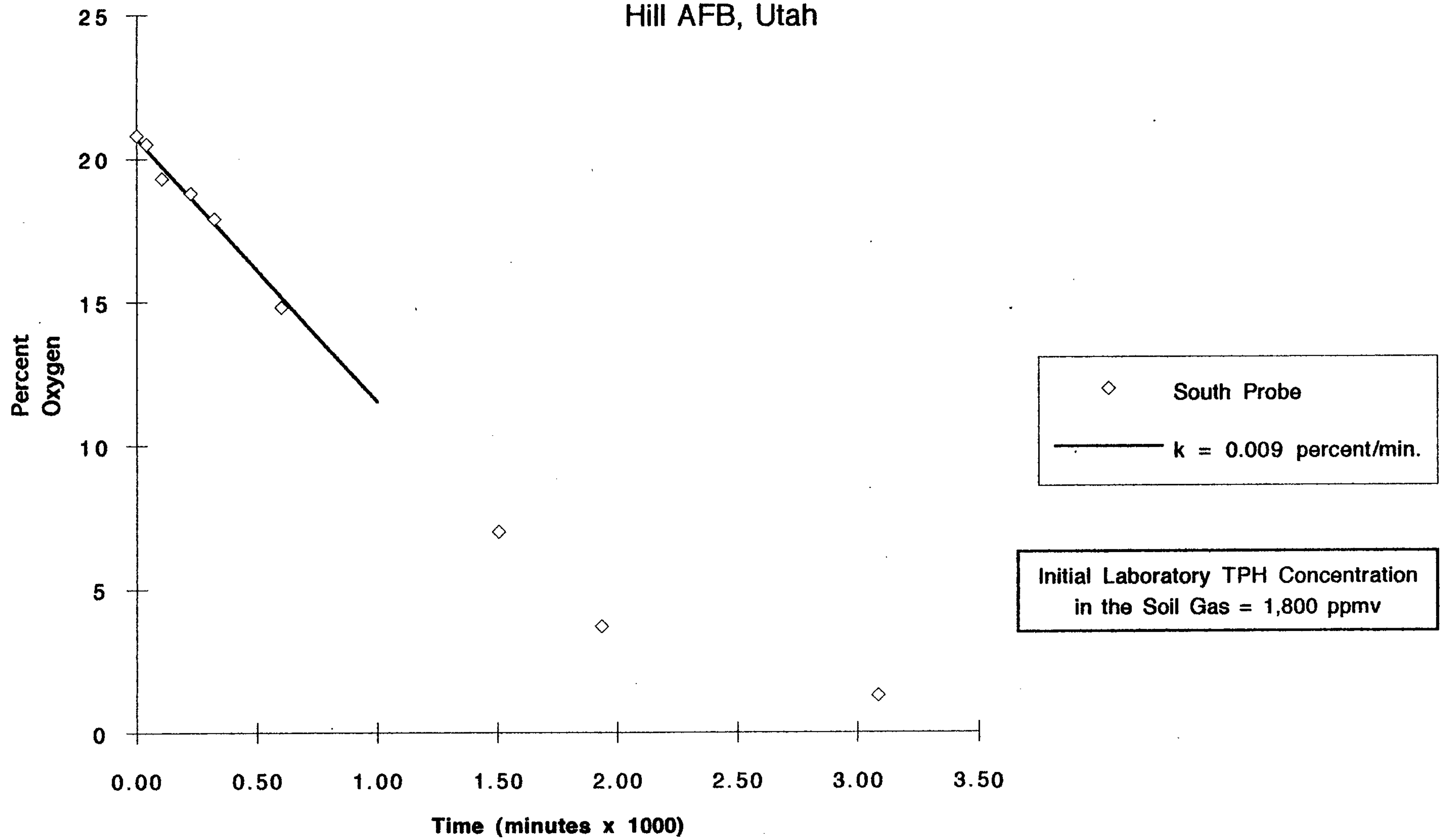
Figure 4.3
Respiration Test
Site 924- SE Probe
Hill AFB, Utah



R.T. Site 924 SE Probe Chart

9/17/92

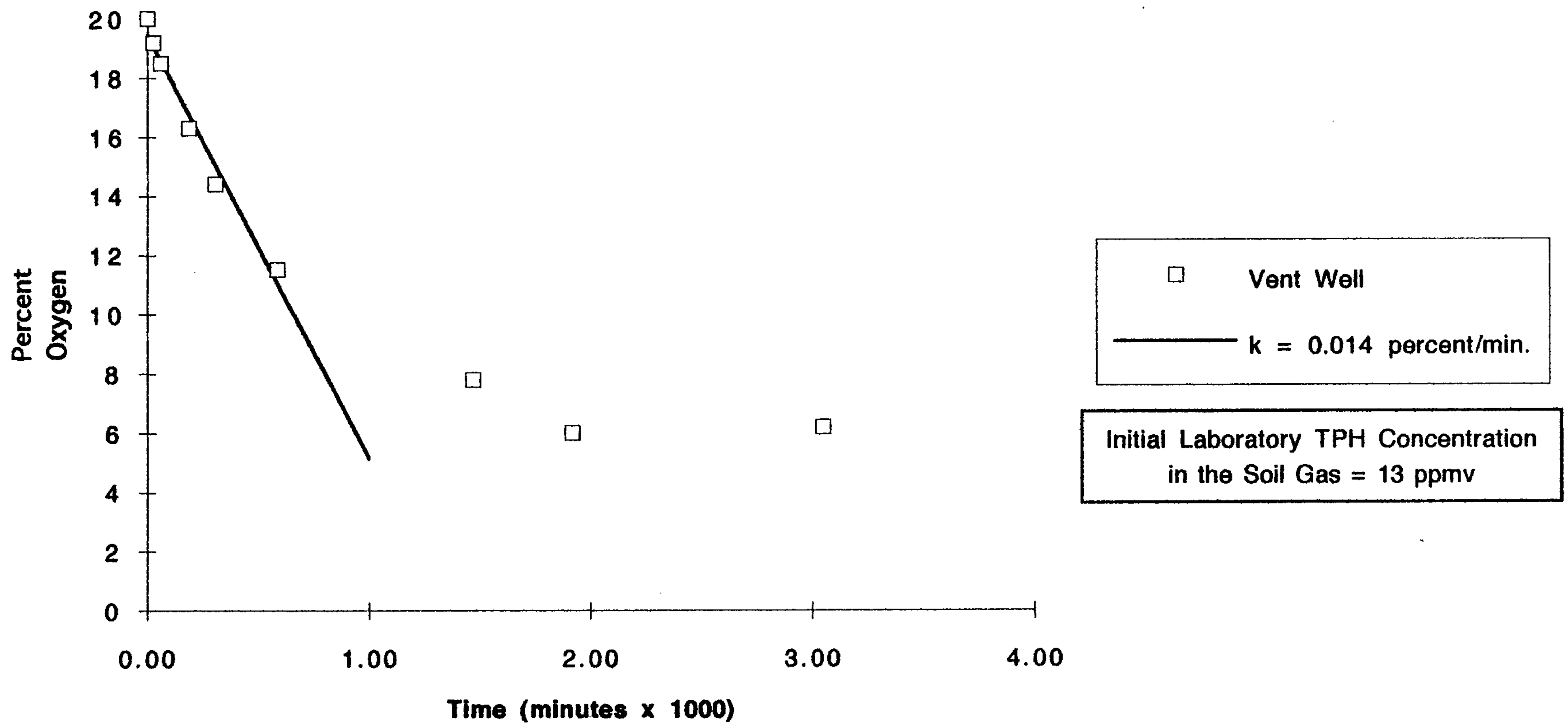
Figure 4.4
Respiration Test
Site 924 - South Probe
Hill AFB, Utah



R. T. Site 924 South Probe

9/17/92

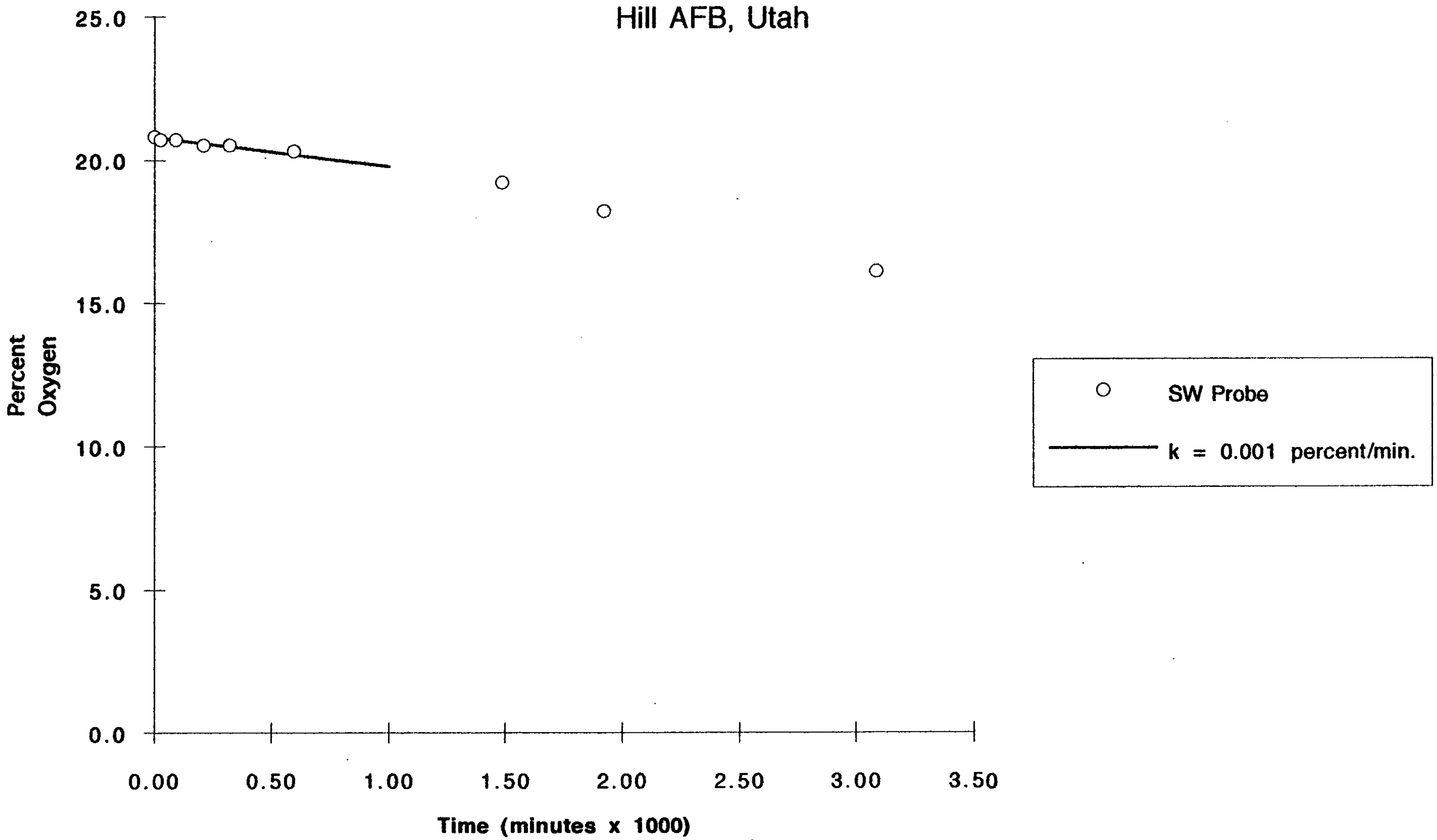
Figure 4.5
Respiration Test
Site 924 - Vent Well
Hill AFB, Utah



R.T. Site 924 Vent Well Chart

9/17/92

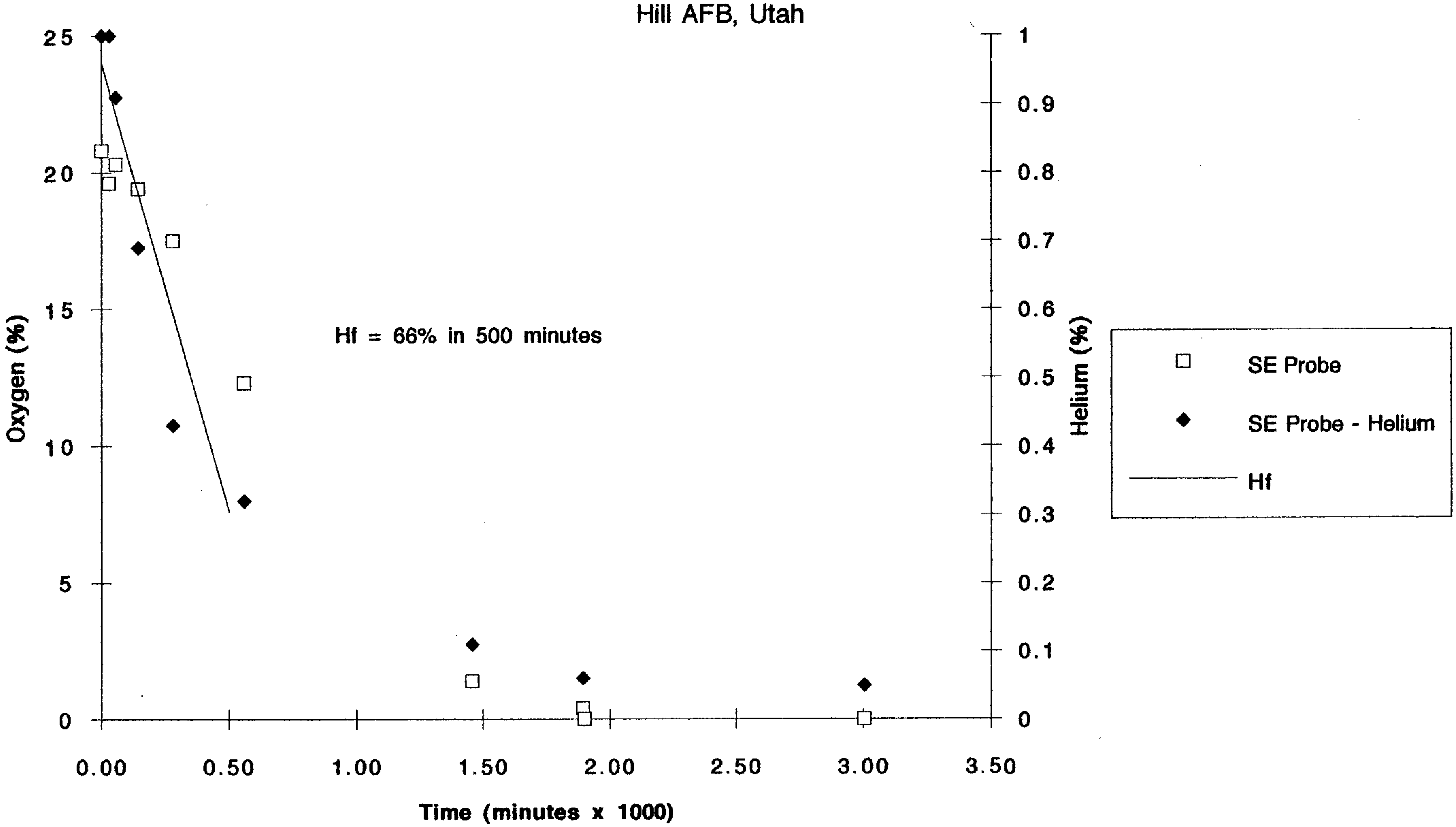
Figure 4.6
Respiration Test
Site 924 - SW Probe
Hill AFB, Utah



R. T. Site 924 SW Probe

8/17/92

Figure 4.7
Respiration Test
Oxygen/Helium Concentrations
Site 924 - SE Probe
Hill AFB, Utah



O2/Helium SE Probe

9/17/92

TABLE 4.5

APPARENT AND CORRECTED OXYGEN UTILIZATION RATES (0-500 MINUTES)

	Apparent O_2 loss (%/min)	Fractional Helium Loss (%)	Fractional O_2 Diffusion (%)	Estimated O_2 Diffusion (%/min)	Corrected O_2 Utilization (%/min)
SW Probe	.001	66**	22**	.003	0
Vent Well	.014	66**	22**	.003	.011
South Probe	.009	66**	22**	.003	.006
SE Probe	.013	66	22	.003	.010

** Based on helium diffusion from the SE Probe

A7-4-10

4.5 Recommendations

Initial bioventing tests at Site 924 indicate that oxygen has been depleted in the contaminated soils, and that air injection is an effective method of increasing aerobic fuel biodegradation. AFCEE has recommended that air injection continue on this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates.

A 2.5-horsepower regenerative blower has been installed at the site (Figure 4.1) to continue a low rate of air injection. In December 1992, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. In July 1993, a final respiration test will be conducted and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of treatment.

Based on the results of the first year of bioventing, AFCEE will recommend one of three options:

1. Continued operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the base in obtaining regulatory approval for upgrading and continued operation.
2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.
3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE could recommend the removal of the blower system and proper abandonment of the horizontal venting pipe.

REFERENCES

Hinchee, R.E., R.N. Miller, D.C. Downey. January 1992. Test Plan and Technical Protocol for a Field Treatability Test for Bioventing. Prepared for Air Force Center for Environmental Excellence. Brooks Air Force Base, Texas.

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James M. Montgomery, Inc., December 1991b. Site Characterization Report for UST Site 924.5, External Draft. Contract F42650-89-D0029, Task 5012.

James M. Montgomery, Inc., July 1992a. Subsurface Investigation Report for UST Site 204.1, Internal Draft. Contract F42650-91-D0031, Task 5002.

James M. Montgomery, Inc., July 1992b. Subsurface Investigation Report for UST Site 214.1, Internal Draft. Contract F42650-89-D0029, Task 5011.

James M. Montgomery, Inc., July 1992c. Abatement and Initial Site Characterization Report for UST Site 228, Final. Contract F42650-91-D0031, Task 5003.

APPENDIX A

SOIL BORING LOGS, WELL AND VAPOR PROBE

COMPLETION DETAILS

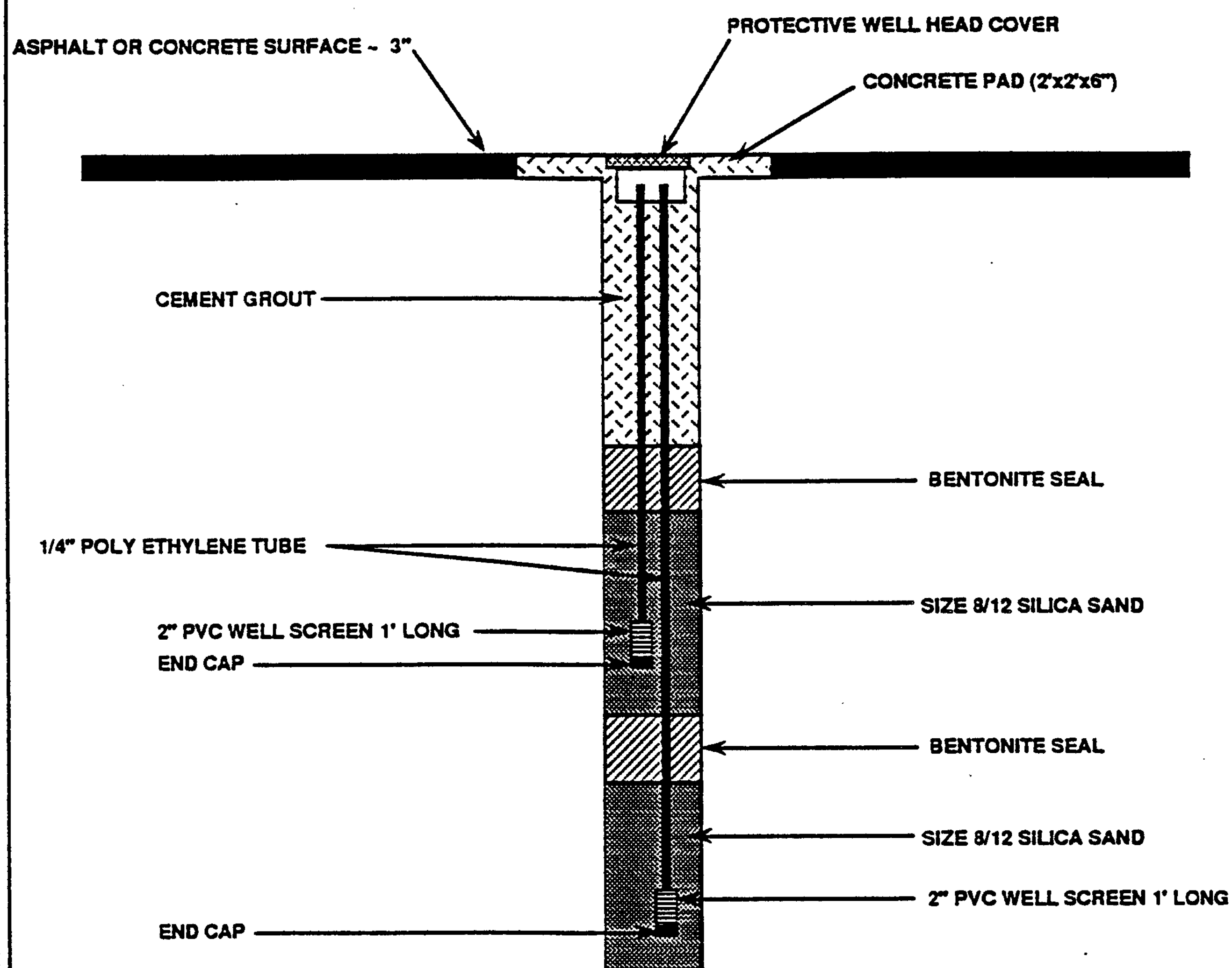
APPENDIX A.1

SOIL BORING LOGS, WELL AND

VAPOR PROBE COMPLETION DETAILS

SITE 204.1

(James M. Montgomery, Inc., July 1992a)



NOTE: THIS DIAGRAM IS NOT TO SCALE

PROJECT NO. 2208.0333

JMM James M. Montgomery

GENERALIZED SOIL VAPOR PROBE COMPLETION DETAIL

HORIZONTAL COORDINATES: 286,166.96N 1,869,092.37E

DATE STARTED: 5-4-92 DATE COMPLETED 5-4-92

GROUND SURFACE ELEVATION (above MSL): 4,780.13

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	BLOW COUNTS	SAMPLE TYPE*	SAMPLE INTERVAL	GRAPHIC LOG	LITHOLOGIC LOG	SOIL VAPOR PROBE COMPLETION DETAIL	ELEVATION (FEET)
0	15	60	25	3.5	12			SM	Asphalt to 3 inches, fill - silty sand, dark grayish brown (10YR4/2), gravel to 1 inch in-diameter, angular to subrounded, medium to fine sand, angular to subrounded, dense, slightly moist.		4780
					17	SS					
					14						
	TR	70	30	4.0	11				Fill - silty sand, dark grayish brown (10YR4/2), gravel to 1/2 inch in diameter, angular to subrounded, medium to fine sand, subangular to subrounded, medium dense, slightly moist.		
					15	SS					
					13						
		70	30	73	10				Silty sand, dark yellowish brown (10YR4/4), medium to fine sand, angular to subrounded, medium dense, moist.		
					11	SS					
					16						
		70	30	77	12						
5											4775
					11	SS					
					12				As above 2 inches.		
		70	30	19	9						
	50	30	20		7	SS		GM	Silty sandy gravels, dark yellowish brown (10YR5/4), gravel to 1 inch in diameter, angular to subrounded, medium to fine sand, angular to subrounded, moist.		
					8						
	50	30	20	304	3						
		70	30		3	SS		SM	Silty sand, dark yellowish brown (10YR4/4), medium to fine sand, angular to subrounded, loose, moist; last 2 inches black hydrocarbon staining and odor present.		
					3						
		70	30	>1000	1				As above, ~2 inches contained hydrocarbon stained soils and strong hydrocarbon odor. SB204A-01 Chemical sample 9.0 to 9.5 feet.		
					1	SS					
10											4770
		70	30	42	2				As above, ~1 inch of hydrocarbon staining.		
					1						
					1	SS					
					1						
		70	30	18	1						
		95	5		2	SS		SP	Poorly graded sand, light yellowish brown (10YR6/4), medium, subangular to subrounded, loose, slightly moist.		
					3						
		95	5	23	3						
		95	5		7	SS			Clay layer 3 inches, strong brown (7.5YR5/6), soft, low plasticity, slightly moist.		
					11				Well graded sand (10YR6/6), fine, angular to subrounded, medium dense, slightly moist.		
15		95	5	367	11						4765
					16	SS					
					24						
		95	5	337	6						
	60	35	5		24	SS		GW	Well graded sandy gravel, yellowish brown (10YR5/4), gravel to 1 1/2 inches in diameter, subangular to subrounded, medium to fine sand, angular to subrounded, medium dense to dense, slightly moist.		
					32						
	60	75	5	5	38						
					53	SS					
					55						
	60	35	5	353	17				SB204A-01 Chemical sample 19.5 to 20.0 feet.		

JMM James M. Montgomery

*SS California Split Spoon Sampler (2.0" I.D.)

HILL AIR FORCE BASE
SB204A-01
(Soil Vapor Probe)

PROJECT NO. 2208.0333

HORIZONTAL COORDINATES:
286,166.96N 1,869,092.37E

DATE STARTED: 5-4-92 DATE COMPLETED 5-4-92
GROUND SURFACE ELEVATION (above MSL): 4,780.13

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	BLOW COUNTS	SAMPLE TYPE*	SAMPLE INTERVAL	GRAPHIC LOG	LITHOLOGIC LOG OF CUTTINGS	ELEVATION (FEET)
20		95	5		23	SS		SP	Poorly graded sand, brownish yellow (10YR6/6), medium sand, angular to subrounded, dense, slightly moist; has hydrocarbon odor. SB204A-01 Chemical sample 20.0 to 20.5 feet.	4760
					38					
	TR	95	5	>10,000	16				As above with trace gravel 1/4 inch in diameter; strong hydrocarbon odor.	
					22	SS				
					31					
	TR	95	5	1100	22					
	40	55	5		24	SS				
					29			GM	As above, gravelly sand, 6 inches increasing gravel to 1/2 inch in diameter, subangular to subrounded, very dense, slightly moist; strong hydrocarbon odor.	
	10	85	5	>10,000	19				Poorly graded gravelly sand, brownish yellow (10YR6/6), gravel to 1/4 inch in diameter, medium sand, subangular to subrounded, very dense, slightly moist; strong hydrocarbon odor.	
					32	SS				
25					34					4755
		95	5	1295					As above (10YR5/4), has hydrocarbon odor.	
		70	30		10			SM	Silty sand, with increasing silt with some minor hydrocarbon gray staining last 1/8 inch.	
					14	SS				
					16					
		70	30	3636	14					
					15	SS				
					15					
30		70	30	7592	16				Poorly graded sand, yellowish brown (10YR5/4), medium sand, subangular to subrounded, dense, slightly moist, still has hydrocarbon odor.	4750
		90	10		23	SS				
					24					
		90	10	267	49			SP	Poorly graded sand, light yellowish brown (10YR6/4), fine to medium sand, subangular to subrounded, very dense, slightly moist; faint hydrocarbon odor.	
					27	SS				
					34					
		90	10	313	26				As above except medium sand only.	
					33	SS				
					35					
35		90	10	200	27					4745
					37	SS				
					43					
		90	10	>10,000	12					
					15	SS				
					27					
		90	10	4	10					
					26	SS				
					38					
	TR	90	10	50	29				Sandy gravel, light yellowish brown (10YR6/4), gravel to 1/2 inch in diameter, subrounded, medium sand, subangular to subrounded, very dense, slightly moist.	
	60	30	10		40	SS		GW		

James M. Montgomery

*SS California Split Spoon Sampler (2.0" I.D.)

HILL AIR FORCE BASE
SB204A-01
(Soil Vapor Probe)

PROJECT NO. 2208.0333

HORIZONTAL COORDINATES:
286,166.96N 1,869,092.37E

DATE STARTED: 5-4-92 DATE COMPLETED 5-4-92
GROUND SURFACE ELEVATION (above MSL): 4,780.13

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	BLOW COUNTS	SAMPLE TYPE*	SAMPLE INTERVAL	GRAPHIC LOG	LITHOLOGIC LOG	SOIL VAPOR PROBE COMPLETION DETAIL	ELEVATION (FEET)
40	60	30	10	56	57 34			GW	Sandy gravel, light yellowish brown (10YR6/4), gravel to 2 inches in diameter, subrounded, medium sand, subangular to subrounded, very dense, slightly moist. SB204A-01 Chemical sample 40.0 to 40.5 feet.		4740
	TR	90	10		51 57	SS		SP	Poorly graded sand, (10YR6/4), trace gravel to 1/4 inch in diameter, medium sand, subangular to subrounded, very dense, slightly moist. SB204A-01 Chemical sample 40.5 to 41.0 feet.		
	TR	90	10	3	9 15 28	SS			As above with increasing fines, gravel to 1/8 inch in diameter.		
45	TR	90	10	3	25 39 46	SS					4735
		70	30	2	30 56 63	SS		SM	Silty sand, light yellowish brown (10YR6/4), medium to fine sand, subangular to subrounded, very dense, slightly moist.		
								T.D. 47.5			
50											4730
55											4725

JMM James M. Montgomery

*SS California Split Spoon Sampler (2.0" I.D.)

HILL AIR FORCE BASE
SB204A-01
(Soil Vapor Probe)

PROJECT NO. 2208.0333

HORIZONTAL COORDINATES:
286,162.40N 1,869,085.13E

DATE STARTED: 5-6-92 DATE COMPLETED 5-6-92
GROUND SURFACE ELEVATION (above MSL): 4,780.22

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	BLOW COUNTS	SAMPLE TYPE*	SAMPLE INTERVAL	GRAPHIC LOG	LITHOLOGIC LOG	ELEVATION (FEET)
0	50	30	20	44	17 25 27	SS		GM	Asphalt to 3 inches, fill - silty sandy gravel, brownish yellow to dark yellowish brown (10YR6/6-3/4), gravel to 1 inch in diameter, angular to subrounded, medium to fine sand, dense, slightly moist; slight hydrocarbon odor.	4780
								SM		
5	TR	70	30	86	11 15 16	SS			Silty sand, dark yellowish brown (10YR4/4), trace gravel to 1/4 inch in diameter, medium to fine sand, medium dense, upper 6 inches very moist; black charcoal present.	4775
10		70	30	297	4 3 4	SS			Silty sand, brown to dark brown to black (10YR4/3-2/1), medium to very fine sand, angular to subrounded, loose, moist; visible hydrocarbon staining and strong hydrocarbon odor. SB204A-02 Chemical sample 11.0 to 11.5 feet.	4770
		70	30	293	9 4 3	SS			Silty sand, brown to dark brown to black (10YR4/3-2/1), medium to very fine sand, angular to subrounded, loose, moist; upper 2 inches black hydrocarbon staining, lower 3 inches brown to dark brown.	
		70	30	3797	3 3 7	SS		SP	As above, yellowish brown (10YR5/4), hydrocarbon staining visible 14 inches. Poorly sorted sand, medium sand, light yellowish brown (10YR6/4), medium sand, angular to subrounded, loose, slightly moist.	
15		95	5	166	2 6 6	SS			Clay, brown to dark brown (7.5YR4/4), very fine sand, low plasticity, medium dense.	4765
		95	5	16	7 5 5	SS			As above (10YR6/4), 1 inch.	
	TR TR	95 70	5 30	0	5 9 5	SS		SM	Silty sand, light yellowish brown (10YR6/4), medium to fine sand, angular to subrounded, medium dense, slightly moist; hydrocarbon odor, 1 inch poorly graded sandy gravel in end of shoe. SB204A-02 Chemical sample 18.5 to 19.0 feet.	
	60	35	5	12	10 27	SS		GW	Well graded sandy gravel, dark yellowish brown (10YR4/4), gravel to 1 1/2 inches in diameter, subrounded, coarse to fine sand, angular to subrounded, slightly moist.	

SOIL VAPOR PROBE COMPLETION DETAIL

James M. Montgomery

*SS California Split Spoon Sampler (2.0" I.D.)

HILL AIR FORCE BASE
SB204A-02
(Soil Vapor Probe)

PROJECT NO. 2208.0333

HORIZONTAL COORDINATES: 286,162.40N 1,869,085.13E

DATE STARTED: 5-6-92 DATE COMPLETED 5-6-92

GROUND SURFACE ELEVATION (above MSL): 4,780.22

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	BLOW COUNTS	SAMPLE TYPE*	GRAPHIC LOG	LITHOLOGIC LOG OF CUTTINGS	ELEVATION (FEET)
20					35		GW	Well graded sandy gravel, dark yellowish brown (10YR4/4), gravel to 1 1/2 inches in diameter, subrounded, coarse to fine sand, angular to subrounded, slightly moist. SB204A-02 Chemical sample 20.0 to 20.5 feet.	4760
25	TR	95	5	6.1	6 14 23	SS	SP	Poorly graded sand, yellowish brown (10YR5/4), trace gravel to 1/4 inch in diameter, angular to subrounded, medium sand, angular to subrounded, medium dense, slightly moist.	4755
30		95 85	5 15	7.2	10 18 24	SS		Poorly graded sand, yellowish brown (10YR4/4), medium sand, angular to subrounded, medium dense, slightly moist; grading into interbedded silty sand and sand, dark yellowish brown (10YR6/4), medium to fine sand, angular to subrounded, medium dense, slightly moist.	4750
35		95	5	6.5	19 22 31	SS		Poorly graded sand, light yellowish brown (10YR6/4), medium sand, subangular to subrounded, dense, slightly moist.	4745

SOIL VAPOR PROBE COMPLETION DETAIL

James M. Montgomery

*SS California Split Spoon Sampler (2.0" I.D.)

HILL AIR FORCE BASE
SB204A-02
(Soil Vapor Probe)

PROJECT NO. 2208.0333

HORIZONTAL COORDINATES:
286,162.40N 1,869,085.13E

DATE STARTED: 5-6-92 DATE COMPLETED 5-6-92
GROUND SURFACE ELEVATION (above MSL): 4,780.22

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	BLOW COUNTS	SAMPLE TYPE*	SAMPLE INTERVAL	GRAPHIC LOG	LITHOLOGIC LOG	SOIL VAPOR PROBE COMPLETION DETAIL	ELEVATION (FEET)
40	TR	95	5	4.5	13 18 24	SS		SP	Poorly graded sand, light yellowish brown (10YR6/4), as above with trace of gravel to 1/8 inch in diameter.		4740
45	TR	95	5	2.8	14 8 7	SS			Well graded sand, pale brown (10YR6/3), trace gravel, medium sand grading to fine sand, angular to subrounded, medium dense, slightly moist.		4735
50		95	5	1.2	13 19 22	SS			As above with iron staining present in sands 1/16 inch thick.		4730
								T.D. 51.5'			
55											4725

JMM James M. Montgomery

*SS California Split Spoon Sampler (2.0" I.D.)

HILL AIR FORCE BASE
SB204A-02
(Soil Vapor Probe)

PROJECT NO. 2208.0333

HORIZONTAL COORDINATES:
286.155.10N 1,869.090.86E

DATE STARTED: 5-7-92 DATE COMPLETED 5-7-92
GROUND SURFACE ELEVATION (above MSL): 4,780.30

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	BLOW COUNTS	SAMPLE TYPE*	GRAPHIC LOG	LITHOLOGIC LOG	ELEVATION (FEET)
0	60	25	15	0	18 / 41 / 44	SS	GM	Asphalt to 3 inches, fill - silty sandy gravel, dark yellowish brown (10YR4/4), gravel to 1/2 inch in diameter, subangular to subrounded, medium to fine sand, very dense, slightly moist.	4780
5	10	65	25	4.2	9 / 12 / 15	SS	SM	Silty sand, dark yellowish brown (10YR4/4), gravel to 1/2 inch in diameter, subrounded, medium dense, slightly moist; charcoal and some wood present.	4775
10		80	20	5.2	5 / 6 / 6	SS		Silty sand, dark yellowish brown to very dark brown (10YR4/4-2/2), medium to fine sand, angular to subrounded, medium dense, have black staining in lower half of the spoon, faint hydrocarbon odor present. SB204A-03 Chemical sample 11.0 to 11.5 feet. Poorly graded sand, dark yellowish brown (10YR4/4), medium, angular to subrounded, medium dense, slightly moist; 2 inches.	4770
		95	5	82.5	6			Silty sand, dark brown (10YR3/3), medium to fine sand, medium dense, slightly moist; showed some hydrocarbon staining, faint hydrocarbon odor.	
		70	30		5	SS		Color change to light yellowish brown (10YR6/4), decreasing fines.	
		85	15		5				
		85	15	3.1	6			As above with color change to brownish yellow for 2 inches (10YR6/6), increasing silt with depth.	
		60	40		6	SS	SP	Poorly graded sand, pale brown (10YR6/3), medium sand, subangular to subrounded, medium dense, slightly moist.	
		95	5		6			Color change to light yellowish brown (10YR6/4).	
15		95	5	4.2	5 / 5 / 9	SS			4765
								SB204A-03 Chemical sample 20.0 to 20.5 feet.	4760
20		95	5	2.1	9			Poorly graded sand, yellowish brown (10YR5/4), medium sand, angular to subrounded, dense, slightly moist.	
	60	35	5		30 / 35	SS		Sandy gravel, light yellowish brown (10YR6/4), gravel to 1 inch in diameter, subangular to subrounded, medium sand, very dense, slightly moist. SB204A-03 Chemical sample 21.0 to 21.5 feet.	

T.D. 21.5'

SOIL VAPOR PROBE COMPLETION DETAIL

JMM James M. Montgomery

*SS California Split Spoon Sampler (2.0" I.D.)

HILL AIR FORCE BASE
SB204A-03
(Soil Vapor Probe)

PROJECT NO. 2208.0333

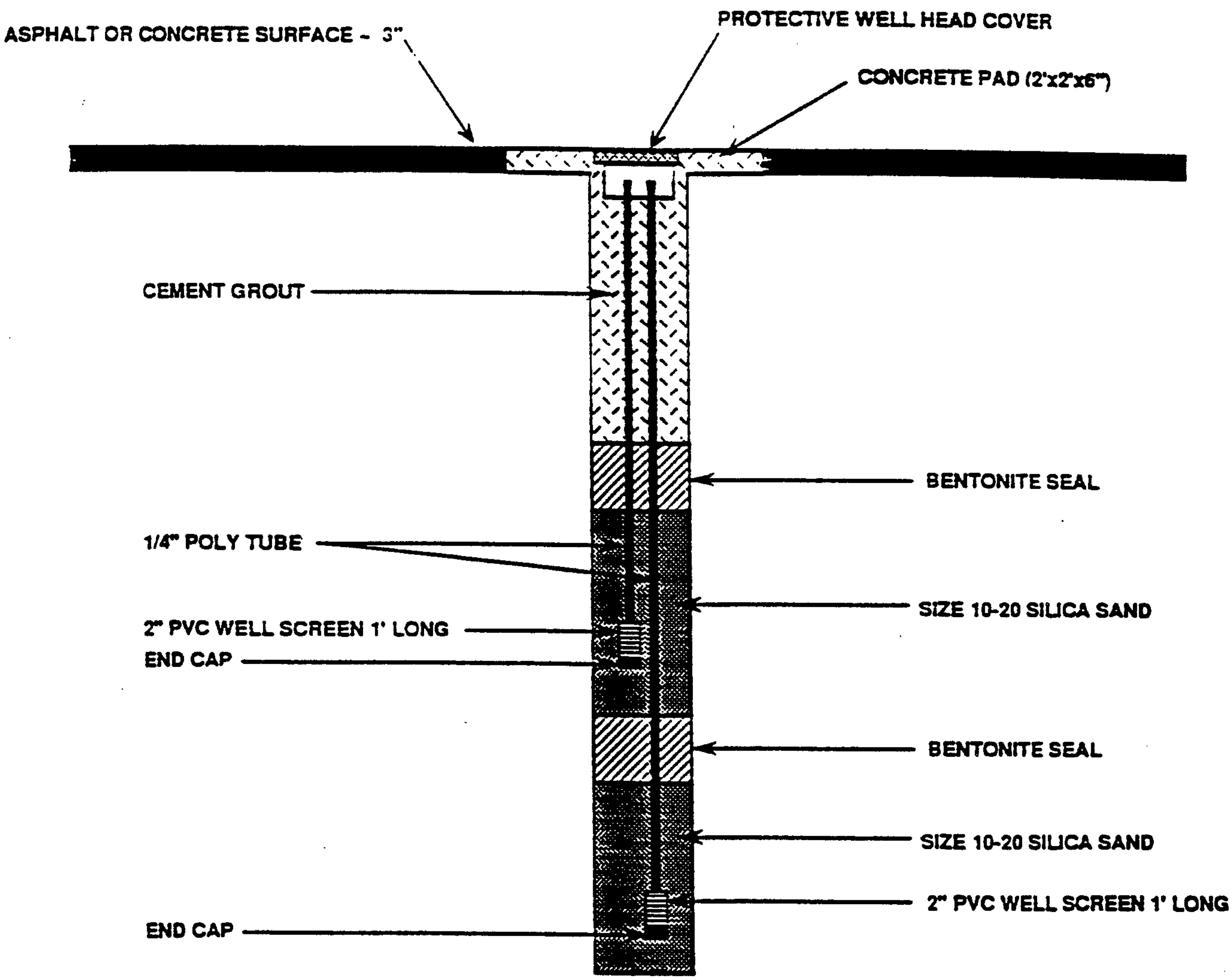
APPENDIX A.2

SOIL BORING LOGS, WELL AND

VAPOR PROBE COMPLETION DETAILS

SITE 214.1

(James M. Montgomery, Inc., July 1992b)



NOTE: THIS DIAGRAM IS NOT TO SCALE

PROJECT NO. 2208.0301

JMM James M. Montgomery

GENERALIZED SOIL VAPOR PROBE COMPLETION DETAIL

HORIZONTAL COORDINATES:
285,951.18N 1,868,959.03E

DATE STARTED:11-5-91 DATE COMPLETED 11-5-91
GROUND SURFACE ELEVATION (above MSL): 4779.30'

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	RECOVERY	SAMPLE TYPE*	GRAPHIC LOG	LITHOLOGIC LOG	ELEVATION (FEET)
0		80	20	2.4	10"	SS	SM	Silty sand, yellowish brown (10YR5/8), medium to very fine sand, subangular to subrounded, low plasticity, soft, moist.	4779
		80	20	0.6	16"	SS			
5						SS		No recovery, sample was plugged with a stone.	4774
		80 60	20 40	2.4	14"	SS		Top 4 inches as above, increasing silt, sand is fine to very fine.	
10		80 55	20 45	3.0	14"	SS		As above, lower 9 inches is clayey sand. Clayey sand, pale brown (10YR6/3), fine to very fine sand, subangular to subrounded, low plasticity, very firm, moist. SB214A-03 Chemical sample 10.0 to 11.0 feet.	4769
		80 60	20 40	2.0	18"	SS		As above with slight color changes (10YR6/4) thinly bedded clayey sands with iron oxide staining on top of the sandy layers.	
		80 95	20 5	3.0	9"	SS		As above, grading into well sorted sand, last 1 inch of sample, coarse to fine.	
15		95	5	2.7	14"	SS	SW	Poorly sorted sand, light yellowish brown (10YR6/4), coarse to fine sand, low plasticity, soft, moist.	4764
		60 95	40 5	1.7	14"	SS	SM	Top 7 inches silty sand, light yellowish brown (10YR5/3), medium to very fine sand, subangular to subrounded, low plasticity, firm, moist. Grading into well sorted sands, light yellowish brown (10YR6/4), medium to very fine sand, low plasticity, soft, moist.	
					17"	SS			

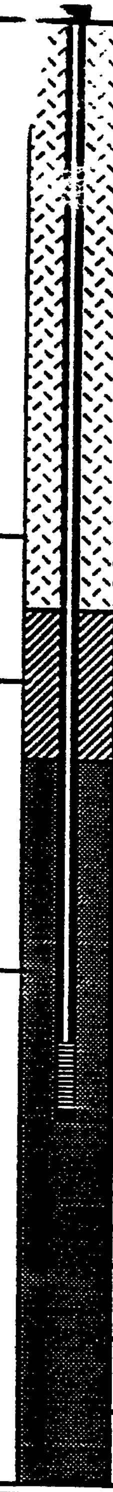
SOIL VAPOR PROBE COMPLETION DETAIL

HORIZONTAL COORDINATES:
285.962.11N 1.868.973.69E

DATE STARTED:11-5-91 DATE COMPLETED 11-5-91
GROUND SURFACE ELEVATION (above MSL): 4.779.15'

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	RECOVERY	SAMPLE TYPE*	SAMPLE INTERVAL	GRAPHIC LOG	LITHOLOGIC LOG	ELEVATION (FEET)
0		70	30	0.6	10"	SS		SM	Silty sand, yellowish brown (10YR5/6), medium to very fine sand, subangular to subrounded, low plasticity, soft, moist.	4779
		85	15	2.0	18"	SS			As above, light yellowish brown (10YR6/4), deceasing silt.	
5		75	25	8.2	12"	SS			Silty sand, light yellowish brown (10YR6/4), fine to very fine sand, subanguiar to subrounded, low plasticity, firm, moist; faint hydrocarbon odor, weathered.	4774
		75 60	25 40	2.7	16"	SS		SC	Clayey sand, light yellowish brown (10YR6/4), fine to very fine sand, subangular to subrounded, low plasticity, firm, saturated to moist; no hydrocarbon odor.	
10		80	20	1.3	18"	SS		SM	Silty sand, light yellowish brown (10YR6/4), fine to very fine sand, subangular to subrounded, low plasticity, soft, moist; also have some layers 0.50 inch of clayey sand.	4769
		85	15	0.6	16"	SS			As above, very pale brown (10YR7/3) with deceasing silt.	
		95	5	3.4	14"	SS		SW	Poorly sorted sand, brown (10YR5/3), coarse to fine sand, low plasticity, soft, moist.	
15	10	85	5	1.3	14"	SS			As above with 10% coarse gravel.	4764
	20	75	5	19.6	8"	SS	▮		Gravelly sand, well sorted (10YR5/3), gravel is coarse to fine, coarse to fine sand, subangular to subrounded, low plasticity, soft, moist. SB214A-02 Chemical sample 18.0 to 19.0 feet.	
	30	65	5	3.0	10"	SS			Increasing gravel.	

PROBE COMPLETION DETAIL



PROJECT NO. 2200.0303

JMM James M. Montgomery

SS California Split Spoon Sampler (2.0" I.D.)
CC Continuous Core

HILL AIR FORCE BASE
SB214A-02
(Vapor Probe)

HORIZONTAL COORDINATES:
285.962.11N 1.868.973.69E

DATE STARTED:11-5-91 DATE COMPLETED 11-5-91
GROUND SURFACE ELEVATION (above MSL): 4,779.15'

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	RECOVERY	SAMPLE TYPE*	SAMPLE INTERVAL	GRAPHIC LOG	LITHOLOGIC LOG	MONITORING WELL COMPLETION DETAIL	ELEVATION (FEET)
20					10"	SS		SWI	No recovery, sampler plugged with a rock, drilled out of 25 feet due to coarse gravels/cobbles.		4759
						SS					
						SS			Poorly sorted sand, brown (10YR5/3), trace gravel, coarse to fine sand, subangular to subrounded, low plasticity, soft, moist.		
25	TR	95	5	4.1	16"	SS			As above.		4754
		80	20	2.7	12"	SS		SM	Silty sand, light yellowish brown (10YR5/4), medium to very fine sand, subangular to subrounded, low plasticity, soft, moist.		
30		70	30	2.4	14"	SS					4749
35											4744

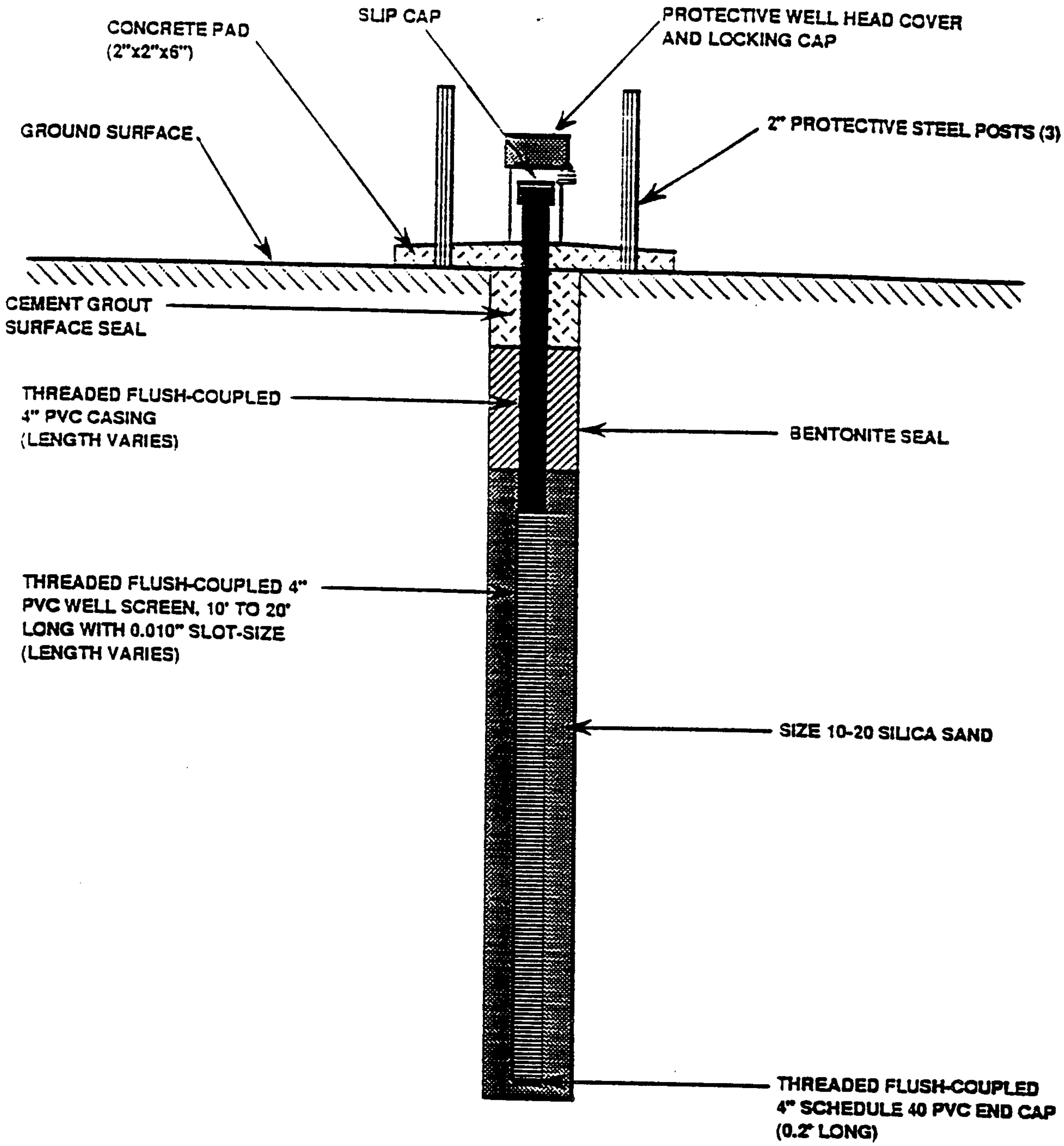
T.D. 31.0'

JMM James M. Montgomery

SS California Split Spoon Sampler (2.0" I.D.)
CC Continuous Core

HILL AIR FORCE BASE
SB214A-02
(Vapor Probe)

PROJECT NO. 2208.0303



NOTE: THIS DIAGRAM IS NOT TO SCALE

JMM James M. Montgomery

GENERALIZED ABOVE GROUND
AIR INJECTION WELL
CONSTRUCTION DETAIL

HORIZONTAL COORDINATES:
285,931.21N 1,868,989.03E

DATE STARTED: 11-1-91 DATE COMPLETED 11-1-91
GROUND SURFACE ELEVATION (above MSL): 4,782.16'

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	RECOVERY	SAMPLE TYPE*	SAMPLE INTERVAL	GRAPHIC LOG	LITHOLOGIC LOG	ELEVATION (FEET)
0		60	40	0.5	6"	SS		SM	Silty sand, yellowish brown (10YR6/6), medium to fine sand, subangular to subrounded, low plasticity, firm, moist.	4782
		60	40	0.5	14"	SS			As above, had approximately 3 inches of dark gray silty sand dark gray (10YR4/1); no real odor, looks stained.	
5		80	20	0.9	16"	SS				4777
		70	30	0.9	18"	SS			As above, had 3 inches of dark gray silty sand, dark gray (10YR4/1), is medium to very fine sand; no hydrocarbon odor, looks stained, not enough to do head space.	
		60	40	1355 last 2" in shoe 1550	18"	SS			Silty sand, yellowish brown (10YR6/6), medium to fine sand, low plasticity, firm, slightly moist; shows iron oxide staining not in bedding.	
10		80	20	1550	18"	SS	11.0–12.0		As above, developed fines last 2 inches in shoe, weathered, had strong hydrocarbon odor. SB214A-01 Chemical sample 11.0 to 12.0 feet.	4772
		60	40	1269	16"	SS				
		95	5	432	18"	SS		SW	Poorly sorted sand, pale brown (10YR6/3), medium to very fine, subangular to subrounded, low plasticity, soft; last 4 inches brown sand (10YR5/3), coarse to medium sand; fainter hydrocarbon odor.	
15	15	80	5	178	18"	SS			Gravelly sand (10YR5/3), coarse to medium sand, subangular to subrounded, low plasticity, soft, moist; still has hydrocarbon odor.	4767
	15	80	5	-	14"	SS			As above, with less hydrocarbon odor.	

INJECTION WELL COMPLETION DETAIL

James M. Montgomery

SS California Split Spoon Sampler (2.0" I.D.)
CC Continuous Core

HILL AIR FORCE BASE
SB214A-01
(Injection Well)

PROJECT NO. 2208.0303

HORIZONTAL COORDINATES:
285.931.21N 1.868.989.03E

DATE STARTED:11-1-91 DATE COMPLETED 11-1-91
GROUND SURFACE ELEVATION (above MSL): 4.782.16'

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	RECOVERY	SAMPLE TYPE*	SAMPLE INTERVAL	GRAPHIC LOG	LITHOLOGIC LOG	INJECTION WELL COMPLETION DETAIL	ELEVATION (FEET)
20	25	70	5	369	3"	SS		SWI	Poorly sorted gravelly sand, brown (10YR5/3), coarse to fine sand, subangular to subrounded, low plasticity, soft, moist; no chemical sample grabbed due to poor recovery, spoon plugged with gravels refusal.		4762
						SS			Drilled to 2.5 feet due to refusal on last spoon.		
25		95	5	329	8"	SS			Poorly sorted sand, pale brown (10YR6/3), coarse to medium sand, subangular to subrounded, low plasticity, soft, moist; strong hydrocarbon odor. Refusal after approximately 8 inches.		4757
		80	20	404	18"	SS		SM	Silty sand, brown (10YR5/4), medium to very fine sand, subangular to subrounded, low plasticity, soft, moist; strong hydrocarbon odor.		
30		80	20	423	14"	SS					4752
		80	20	419	6"	SS					
		95	5	337	18"	SS		SWI	Poorly sorted sand, pale brown (10YR6/3), coarse to fine, subangular to subrounded, low plasticity, soft, moist; hydrocarbon odor.		
35		95	5	154	16"	SS					4747
		95	5	160	14"	SS					
		95	5	241					As above (10YR6/2), with thin layers of silty sand, see some iron oxide staining 1-2 mm thick.		
		70	30		16"	SS					

James M. Montgomery

SS California Split Spoon Sampler (2.0" I.D.)
CC Continuous Core

HILL AIR FORCE BASE
SB214A-01
(Injection Well)

PROJECT NO. 2208.0303

HORIZONTAL COORDINATES:
285,931.21N 1,368,989.03E

DATE STARTED: 11-1-91 DATE COMPLETED 11-1-91
GROUND SURFACE ELEVATION (above MSL): 4,782.16'

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	RECOVERY	SAMPLE TYPE*	GRAPHIC LOG	LITHOLOGIC LOG	ELEVATION (FEET)
40					16"	SS	SW		4742
		95	5	146	16"	SS		As above (10YR6/2), with thin layers of silty sand at ~0.5 inches, see some iron oxide staining 1-2 mm thick.	
		95	5	156					
		70	30		16"	SS			
45								SB214A-02 Chemical sample 44.0 to 45.0 feet. Drillers overdrilled.	4737
						SS			
50		95	5	17.9	18"	SS		Poorly sorted sand, light yellowish brown (10YR6/4), coarse to medium sand, subangular to subrounded, low plasticity, soft, slightly moist; no real hydrocarbon odor.	4732
		95	5	5.2					
		70	30		18"	SS			
		95	5	3.7				As above, increasing silt.	
55		70	30		16"	SS			4727
		95	5	2.8	4"	SS	SM	Silty sand, light yellowish brown (10YR6/4), medium to fine sand, subangular to subrounded, low plasticity, soft, slightly moist.	
		95	5	2.8	12"	SS		SB214A-02 Chemical sample 57.0 to 58.0 feet.	
								T.D. 60.0'	

INJECTION WELL COMPLETION DETAIL

James M. Montgomery

SS California Split Spoon Sampler (2.0" I.D.)
CC Continuous Core

HILL AIR FORCE BASE
SB214A-01
(Injection Well)

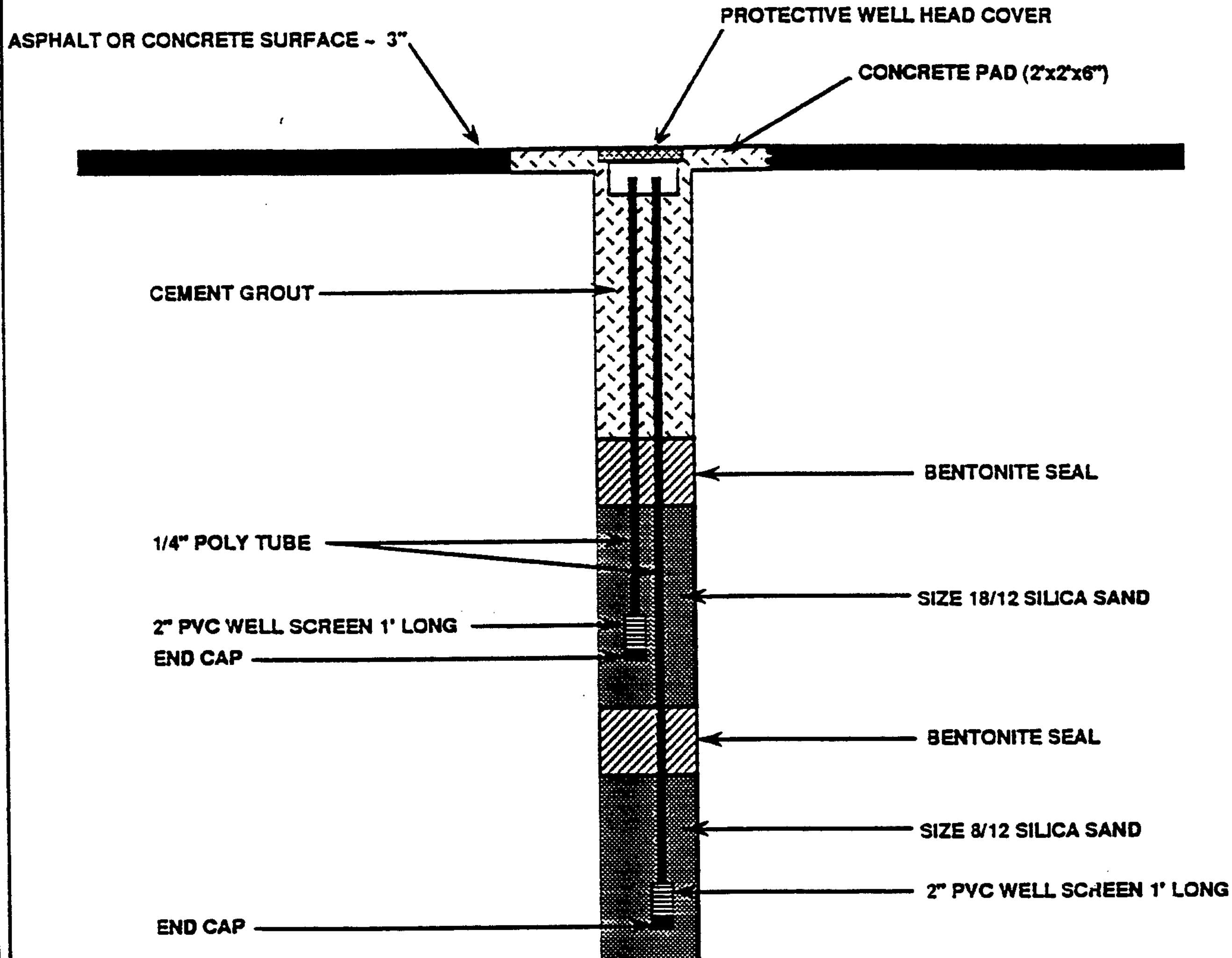
PROJECT NO. 220[illegible]3

APPENDIX A.3

SOIL BORING LOGS, WELL AND VAPOR PROBE COMPLETION DETAILS

SITE 228

(James M. Montgomery, Inc., July 1992c)



NOTE: THIS DIAGRAM IS NOT TO SCALE

PROJECT NO. 2208.0343

JMM James M. Montgomery

GENERALIZED SOIL VAPOR PROBE COMPLETION DETAIL

HORIZONTAL COORDINATES: ?N ?E

DATE STARTED: 3-18-92 **DATE COMPLETED** 3-18-92
GROUND SURFACE ELEVATION (above MSL):

DEPTH (FEET)	GRAIN SIZE % GRAVEL	GRAIN SIZE % SAND	GRAIN SIZE % FINES	MAX PID READING (ppm)	BLOW COUNTS	SAMPLE TYPE*	SAMPLE INTERVAL	GRAPHIC LOG	LITHOLOGIC LOG	SOIL VAPOR PROBE COMPLETION DETAIL	ELEVATION (FEET)
0	60	30	10	0.4	6			GM	Asphalt to 3 inches, fill - silty sandy gravel, dark yellowish brown (10YR4/4), gravels to 1 inch in diameter, subangular, medium to fine sand, angular to subrounded, loose, slightly moist.		4782
					3	C					
					3						
	TR	70	30	0	5			SM	Silty sand, dark yellowish brown (10YR4/4), trace of gravel to 1/2 inch in diameter, subrounded, medium to fine sand, angular to subrounded, loose, slightly moist.		
					4	C					
					3						
		70	30	0.3	4						
		85	15		6	C		SP	Poorly graded sand, light yellowish brown (10YR6/4), fine sand, subangular to subrounded, medium dense, slightly moist.		
					8				As above with decreasing fines.		
		90	10	15	8						
5					8	C					4777
					7						
		90	10	0.4	11						
		60	40		9	C			Silty sand, dark yellowish brown (10YR4/4), fine to very fine sand, medium dense, slightly moist.		
		90	10		12						
		90	10	6.8	7				Poorly graded sand, light yellowish brown (10YR6/4), fine sand, subangular to subrounded, medium dense, slightly moist.		
					10	C					
					19						
		95	5	8.4	15						
10					21	C					4772
					24						
		95	5	1.3	16						
					21	C					
					22						
		95	5	1.3	8			SW	Well graded sands, light yellowish brown (10YR6/4), medium to fine sands, angular to subrounded, medium dense, slightly moist.		
					11	C					
					15						
		95	5	14	9				As above, yellowish brown (10YR5/4).		
					16	C					
					22						
15	TR	85	5	4.0	17				As above with gravels to 1 inch in diameter, subrounded.		4767
					21	C					
					25						
	20	75	5	0.9	9				Well graded sand, yellowish brown (10YR5/4), gravel to 1/2 inch in diameter, subrounded, medium dense, slightly moist.		
					17	C					
					23						
	20	75	5	2.1	10						
		95	5		16	C		SP	Poorly graded sand, light yellowish brown (10YR6/4), fine sand, subangular to subrounded, medium dense, slightly moist.		
					24						
	10	85	5	0.4	8						

JMM James M. Montgomery

* C California Split Spoon Sampler (2.0" I.D.)

HILL AIR FORCE BASE
T-228-1-VP-U-92-HF
(Soil Vapor Probe)

PROJECT NO. 2208.0343

HORIZONTAL COORDINATES: ?N ?E

DATE STARTED: 3-18-92 DATE COMPLETED 3-18-92

GROUND SURFACE ELEVATION (above MSL):

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	BLOW COUNTS	SAMPLE TYPE*	GRAPHIC LOG	LITHOLOGIC LOG	ELEVATION (FEET)
20					17	C	SP	Poorly graded sand as above with gravel to 1/2 inch in diameter, subrounded, medium sand, very dense. T-228-1-VW-92-HF Chemical sample 20.0 to 20.5 feet.	4762
					22				
	10	85	5	2.8	21				
					34	C			
					41				
	20	75	5	4.7	20		SW	Well graded sand, light yellowish brown (10YR6/4), gravel to 1/2 inch in diameter, subrounded, coarse to fine sand, angular to subrounded, dense.	
					29	C			
					36				
	30	65	5	1.8	7			As above with gravel to 1 1/2 inches in diameter, medium to fine sands, angular to subrounded, medium dense to dense, slightly moist.	
					18	C			
25	30	65	5	52	22		CL	Clay, brown (7.5YR5/4), low plasticity, moist, faint hydrocarbon odor in clay.	4757
		20	80		14		SW		
					17	C			
					19				
	30	65	5	>1,000	13			As above with gravel to 1/2 inch in diameter, subrounded, medium to fine sand, angular to subrounded, dense to very dense, moist; strong hydrocarbon odor and staining.	
		85	15		24	C	SM	Silty sand, pale brown (10YR6/3), fine sand, angular to subrounded, dense, moist; last 5 inches has strong hydrocarbon odor and slight staining.	
					30				
		85	15	>1,000	14			Well graded sand as above (10YR6/4).	
	30	65	5				SW	Poorly graded sand, light gray (10YR7/2), fine sand, angular to subrounded, medium dense, dry to slightly moist.	
		95	5		16	C	SP		
		60	40		10		SC	Clayey sand, dark grayish brown (10YR4/2), very fine to fine sand, very moist; faint hydrocarbon odor, weathered.	
30		75	25	22	9		SM	Silty sand, dark yellowish brown (10YR4/4), medium to fine sand, angular to subrounded, medium dense, moist.	4752
		90	10		13	C	SP	Poorly graded sand, light yellowish brown (10YR6/4), fine sand, angular to subrounded, medium dense, dry to slightly moist.	
		60	40		24		SM	Silty sand (10YR4/4), angular with increasing silt.	
		95	5	12	14		SP	Poorly graded sand, light yellowish brown (10YR6/4), fine sand, angular to subrounded, dense, slightly moist.	
					22	C			
					27				
		95	5	2.2	28				
					37	C			
					44			T-228-1-VW-92-HF Chemical sample 34.0 to 34.5 feet.	
35		70	30	3.6	18		SM	Silty sand layer to 8 inches, light yellowish brown (10YR6/4), fine sand, angular to subrounded, dense, moist.	4747
		95	5		30	C	SP	Poorly graded sand, light yellowish brown (10YR6/4), fine sand, angular to subrounded, very dense, slightly moist.	
					37				
		95	5	3.4	16				
					28	C			
					35				
		95	5	2.5	20				
					36	C		As above with color change to yellowish brown (10YR5/4).	
					45				
		95	5		37			Well graded gravelly sand, (10YR6/4), gravel to 1/2 inch in diameter, subrounded, coarse to very fine sand, subangular to subrounded, very dense, slightly moist.	
	40	55	5	5.4	63	C	SW		

SOIL VAPOR PROBE COMPLETION DETAIL

* C California Split Spoon Sampler (2.0" I.D.)

JMM James M. Montgomery

PROJECT NO. 2208.0343

HILL AIR FORCE BASE
T-228-1-VP-U-92-HF
(Soil Vapor Probe)

HORIZONTAL COORDINATES: ?N ?E

DATE STARTED: 3-18-92 DATE COMPLETED 3-18-92
GROUND SURFACE ELEVATION (above MSL):

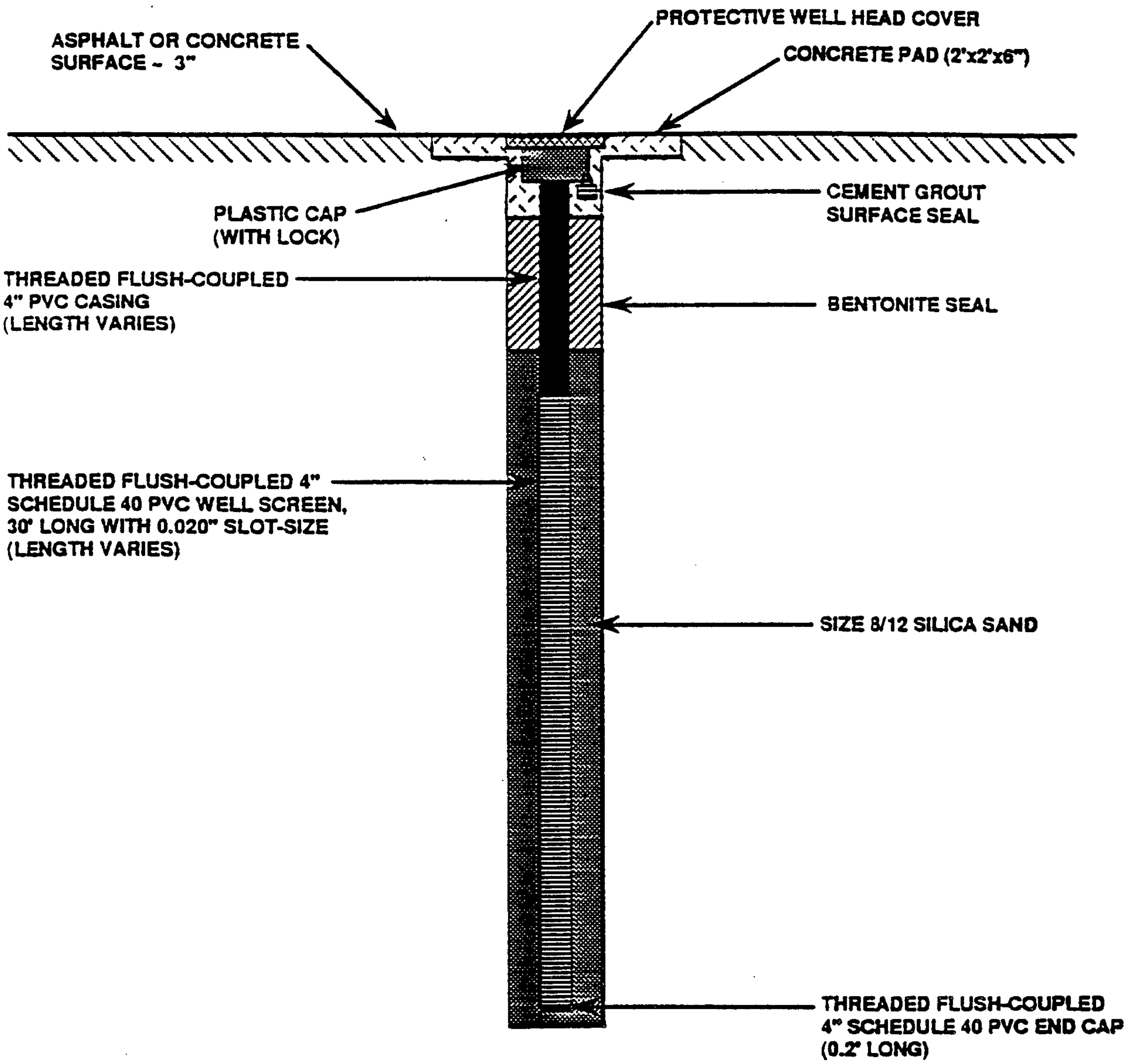
DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	BLOW COUNTS	SAMPLE TYPE*	SAMPLE INTERVAL	GRAPHIC LOG	LITHOLOGIC LOG	SOIL VAPOR PROBE COMPLETION DETAIL	ELEVATION (FEET)
40					82			SW	Well graded gravelly sand (10YR5/4), gravel to 1 inch in diameter, subrounded, medium to fine sand, angular to subrounded, very dense, slightly moist.		4742
	40	55	5	8.6	12	C					
		40	60		27			CL	Sandy clay, dark yellowish brown (10YR4/6), low plasticity, very stiff, moist.		
					36			SW	Well graded gravelly sand as above (10YR5/4), with gravel to 1/2 inch in diameter, subrounded, medium to fine sand, angular to subrounded, dense to very dense, slightly moist; some iron staining in bedding 1/8 inch thick.		
	20	65	5	2.0	19						
					35	C					
					43						
					15						
	20	65	5	0.4	27	C					
45		95	5		39			SP	Poorly graded sand, yellowish brown (10YR5/4), fine sand, subangular to subrounded, very dense, slightly moist; some iron staining present to 1/8 inch thick.		4737
		95	5	2.4	18						
		70	30						Silty sand interbedded with poorly graded sand, yellowish brown, subangular to subrounded, dense, moist.		
		95	5		30	C					
		95	5		40				Poorly graded sand as above, very dense.		
	TR	95	5	0.9	14				Poorly graded sand, light yellowish brown (10YR6/4), trace of gravel to 1/4 inch in diameter, fine sand, angular to subrounded, dense, slightly moist; abundant iron staining in bedding 1/8 inch thick.		
					19	C					
					29						
	TR	95	5	0.5	20				Silty sand interbedded with poorly graded sand, yellowish brown (10YR5/4), fine to very fine sand, angular to subrounded, dense, moist.		
		60	40		18	C					
					22						
50								T.D. 49.5'			4732
55											4727

James M. Montgomery

* C California Split Spoon Sampler (2.0" I.D.)

HILL AIR FORCE BASE
T-228-1-VP-U-92-HF
(Soil Vapor Probe)

PROJECT NO. 2208.0343



NOTE: THIS DIAGRAM IS NOT TO SCALE

James M. Montgomery

PROJECT NO. 2208.0343

GENERALIZED FLUSH MOUNT AIR INJECTION WELL CONSTRUCTION DETAIL

HORIZONTAL COORDINATES:
?N ?E

DATE STARTED: 5-19-92 DATE COMPLETED 5-19-92
GROUND SURFACE ELEVATION (above MSL):

DEPTH (FEET)	GRAIN SIZE % GRAVEL	GRAIN SIZE % SAND	GRAIN SIZE % FINES	MAX PID READING (ppm)	BLOW COUNTS	SAMPLE TYPE*	SAMPLE INTERVAL	GRAPHIC LOG	LITHOLOGIC LOG	VAPOR WELL COMPLETION DETAIL	ELEVATION (FEET)
0	50	35	15	0.5	7, 8, 11	C		GM	Asphalt to 3 inches, fill -silty sandy gravel (10YR2/1), gravel to 1/2 inch in diameter, subangular, medium to very fine sand, angular to subrounded, medium dense, slightly moist.		472[illegible]
		75	25					SM	Silty sand, dark yellowish brown (10YR4/6), medium to very fine sand, angular to subrounded, medium dense, moist.		
5		75	25	0.6	4, 3, 5	C			As above.		471[illegible]
10		75	25	0.4	5, 4, 4	C			Silty sand, yellowish brown (10YR5/4), medium to fine sand, angular to subrounded, loose, moist; silty lenses present with iron staining.		4712
15	TR	95	5	0.9	6, 10, 9	C		SW	Well graded sand, light yellowish brown (10YR6/4), trace gravel to 1/2 inch in diameter, subrounded, medium to very fine sand, angular to subrounded, medium dense, slightly moist.		4707

JMM James M. Montgomery

* C California Split Spoon Sampler (2.0" I.D.)

PROJECT NO. 2208.0343

HILL AIR FORCE BASE
T-228-2-VW-U-92-HF
(Vapor Well)

HORIZONTAL COORDINATES: ?N ?E

DATE STARTED: 5-19-92 DATE COMPLETED 5-19-92

GROUND SURFACE ELEVATION (above MSL):

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX PID READING (ppm)	BLOW COUNTS	SAMPLE TYPE*	GRAPHIC LOG	ELEVATION (FEET)
20		80	20	0.6	5		SM	4702
	10	85	5		10	C	SP	
					14			
25	TR	95	5	0.5	7		SW	4697
					13	C		
					17			
	TR	95	5	>1000	9			
		45	55		6	C	CL	
					16			
		45	55	>1000	16		SW	
	TR	95	5		34	C	SC	
		55	45		29			
					11		SP	
30		55	45	20	21	C		4692
		95	5		33			
		95	5	4.2	38		GW	
	50	45	5		63	C		
					87			
35								4687

LITHOLOGIC LOG OF CUTTINGS

Silty sand, light yellowish brown (10YR6/4), medium to fine sand, angular to subrounded, medium dense, slightly moist.

Poorly graded sand, pale brown (10YR6/3), gravel to 1 inch in diameter, subrounded, fine sand, angular to subrounded, medium dense, slightly moist.

T-228-2-BH-92-HF Chemical sample 20.0 to 20.5 feet.

Well graded sand, light yellowish brown (10YR6/4), trace gravel to 1/4 inch in diameter, subrounded, medium to very fine sand, angular to subrounded, medium dense, slightly moist; shows iron staining interbedded 1/4 inch thick.

Sandy clay, dark yellowish brown (10YR4/4), fine to very fine, medium dense, slightly moist; small clear sand stringers in clay 1/4 inch thick, iron staining present, strong hydrocarbon odors, staining to (10YR5/1), gray in bottom of the shoe.

T-228-2-BH-92-HF Chemical sample 27.5 to 28.0 feet.

As above (10YR4/4).

Well sorted sand, light yellowish brown (10YR6/4), trace gravel to 1/4 inch in diameter, coarse to fine sand, angular to subrounded, very dense, slightly moist, hydrocarbon odor and staining.

Clayey sand, brown to dark brown (10YR4/3), fine to very fine sand, very dense, moist; strong hydrocarbon odor and minor staining.

Poorly graded sand, light yellowish brown (10YR6/4), fine sand, angular to subrounded, very dense, slightly moist, strong hydrocarbon odor in top 6 inches of spoon deceasing with depth.

Well graded gravel, light yellowish brown (10YR6/4), gravel to 1/2 inch in diameter, subrounded, coarse to fine sand, angular to subrounded, very dense, slightly moist.

T-228-1-BH-92-HF Chemical sample 32.0 to 32.5 feet.

T.D. 40.5'

VAPOR WELL COMPLETION DETAIL

JMM James M. Montgomery

* C California Split Spoon Sampler (2.0" I.D.)

HILL AIR FORCE BASE
T-228-2-VW-U-92-HF
(Vapor Well)

PROJECT NO. 2208.0343

APPENDIX B

BLOWER OPERATION AND MAINTENANCE CHECKLIST

SYSTEM MAINTENANCE

1 BLOWER/MOTOR MAINTENANCE

The blower and motor are relatively maintenance free. There is no lubrication required because the blower and motor have sealed bearings. To avoid passing solids through the blower, an air filter has been installed inline before the blower. If a blower system is in need of repair, please contact John Ratz at (303) 831-8100.

2 FILTER MAINTENANCE

To avoid damage caused by passing solids through the blower an air filter has been installed inline before the blower. By design, Gast regenerative blowers are able to ingest small quantities of particles without damage. However, continuous ingestion of solids will damage or imbalance the impellers. The inline air filter will prevent solids from entering the blower and is rated at 99 percent efficiency to 10 microns.

The filter element is a polyester cloth and is cleanable and replaceable. The filter should be checked weekly for the first two months of operation. The air filter should be cleaned or replaced when the pressure difference across the filter reaches 15 to 20 inches of water. It will be up to Hill AFB to determine the best schedule for filter cleaning and/or replacement depending on the results of the initial observations.

The filter can be checked after turning off the blower system. To remove the filter, loosen the clamps, lift the metal top off the air filter, and lift the air filter from the metal housing. When replacing the filter, be careful that the rubber seals remain in place. The filter is manufactured by Solberg Manufacturing, Inc. in Itasca, Illinois. Their phone number is (708) 773-1363. The filters can also be obtained through Fluid Technology, Inc. in Denver, Colorado. The contacts there are Mr. Bob Cook and Mr. Greg Sparks and they can be reached at (303) 233-7400. It is recommended that Hill AFB keep at least two spare air filters at the site.

3 BLOWER PERFORMANCE MONITORING

To monitor the blower performance, vacuum, pressure, and temperature will be measured. These data will be recorded on the data collection sheets provided. All measurements will be taken at the same time while the system is running.

3.1 Pressure/Vacuum

Open the shed roof and record the pressure and vacuum readings directly from the gauges in inches of water. Record the measurements on the data collection sheet provided.

3.2 Temperature

Open the shed roof and record the temperature readings directly from the gauges in degrees Fahrenheit. Record the measurements on the data collection sheet provided.

3.3 Offgas Monitoring

On the extraction system at Site 214.1, a sampling port has been placed in the exhaust piping so that the offgas constituents may be monitored. The frequency of off-gas sampling may be dictated by the air permit.

To collect a sample, open the shed roof and attach an evacuated 5-liter Tedlar bag to the exhaust sampling port. Open the port valve and allow the Tedlar bag to fill. Close the Tedlar bag valve and the sampling port.

Note: Because of the altitude differences sample bags should be only 2/3 full when shipped. Full bags will explode or be more likely to develop leaks.

4 MONITORING SCHEDULE

The following monitoring schedule is recommended for this system. During the initial months of operation, more frequent monitoring is recommended to ensure that any start up problems are quickly corrected. Data collection sheets have been provided to assist your data collection.

Monitoring Item	Monitoring Frequency
Blower Vacuum and temperature	Weekly for the first 2 months of operation. Hill AFB personnel may optimize the schedule depending on the results of initial observations.
Offgas Monitoring	As dictated by the air permit.

BLOWER EXTRACTION SYSTEM DATA COLLECTION SHEET

SITE:________

DATE	TIME	INLET VACUUM 1 (IN. WATER) a/	INLET TEMP. (DEGREES F) a/	INLET VACUUM 2 (IN. WATER) b/	OUTLET TEMP. (DEGREES F) c/	FILTER CHANGED (Y or N)	BLOWER FUNCTIONING UPON ARRIVAL (Y or N)	COMMENTS	CHECKED BY

a/ Gauge is located between the well and the air filter.
b/ Gauge is located between the air filter and the blower unit.
c/ Gauge is located on the blower outlet piping.

BLOWER INJECTION SYSTEM DATA COLLECTION SHEET

SITE:________

DATE	TIME	INLET VACUUM (IN. WATER)	OUTLET TEMP. (DEGREES F)	OUTLET PRESSURE (IN. WATER)	FILTER CHANGED (Y or N)	BLOWER FUNCTIONING UPON ARRIVAL (Y or N)	COMMENTS	CHECKED BY